Acta Scientiarum
http://periodicos.uem.br/ojs/acta
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v41i1.36493

PASTURE AND FORAGE UTILIZATION

Quality of sorghum silage with leucaena

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ASTRACT. This study evaluated the effect of increasing levels of leucaena forage in sorghum: forage. In addition to pure sorghum, it was evaluated different levels of inclusion of leucaena (15, 30 and 50%) at the time of ensiling. Forage was ensiled in PVC tubes (100 mm diameter, 500 mm length) under the density of 500 – 600 kg m^{-3}, a total of 20 silos were prepared, which were opened 35 days after ensiling. There was no effect ($p > 0.05$) of leucaena inclusion levels for pH, water activity (Aw) and total ammonia nitrogen (total NH_3-N). There was an increasing linear effect ($p < 0.05$) for the content of dry matter (DM), crude protein (CP) and lignin that increased from 33.47 to 34.75%, 7.82 to 16.05% and from 7.29 to 9.93%, at the levels from 0 to 50% inclusion of leucaena, respectively. There was a decreasing linear effect ($p < 0.05$) for neutral detergent fiber corrected for ash and protein (NDF_{cp}) and hemicellulose, which reduced from 56.65 to 48.37% and from 24.07 to 17.67% at the levels of 0 and 50% inclusion, respectively. For the ash content, there was a quadratic effect ($p < 0.05$), with a maximum at 8.3% with 8.9% inclusion of leucaena. The inclusion of up to 50% leucaena into sorghum silage is recommended, because, in addition to maintaining the fermentation quality, it also improved nutritional quality of sorghum silage.

Keywords: chemical composition; fermentation; food preservation; legume.

Received on March 29, 2017.
Accepted on August 29, 2017.

Introduction

The use of sorghum in animal feed has shown significant growth in recent years, mainly due to its higher resistance to water stress when compared to corn (Alves et al., 2012). However, its low crude protein, phosphorus and calcium contents are limiting factors for intake and digestibility, making it necessary to supplement with protein concentrates, which leads to higher costs in animal production (Oliveira et al., 2010; Rezende et al., 2011).

An alternative little explored is the use of legumes in the production of silage, it is known that the addition of legumes into grass silage improves the quality of the ensiled mass by increasing the protein content, improving nutrient digestibility, intake and aspects related to the production like weight gain and milk production, due to its high nutritional value (Epifanio et al., 2016; Santana, Cisneros, Martínez, & Pascual, 2015). It is possible to ensile almost all types of forage; however, few species meet the requirements of quantity and quality, and it is important to analyze which species are more economically and nutritionally desirable. Silages of legume alone have poor quality due to high buffering power and low soluble carbohydrate content (Lima, Lourenço, Díaz, Castro, & Fievez, 2010). Nevertheless, the use of legumes mixed with grasses improves the quality of the ensiled mass and increases the protein content when compared to the silage of corn or sorghum alone (Leonel et al., 2008; Lima-Orozco, Castro-Alegría, & Fievez, 2013).

The addition of leucaena (*Leucaena leucocephala*) may be a good option for ensiling with sorghum due to its nutritional qualities, tolerance to water stress and its high productivity (Silva et al., 2015), and there is little known about this type of silage. In this sense, the goal of this study was to evaluate the effects of leucaena addition on sorghum silage at the time of ensiling.

Material and methods

The work was carried out in the area belonging to the Department of Agrarian Sciences, State University of Montes Claros, State of Minas Gerais, campus Janaúba, located at 21°14’ South Latitude and 45°00’ West Longitude of Greenwich, with an average elevation of 910 m.

The sorghum genotype (*Sorghum bicolor* L. Moench) used was VOLUMAX, grown at the Experimental Farm of Embrapa Corn and Sorghum, located in the municipality of Nova Porteirinha, northern State of Minas Gerais, at 15° 48'10" South Latitude and 43°18'03" West longitude. Leucaena was harvested from the agrostólogico field of the State University of Montes Claros, in plants with approximately 0.8 cm thickness of branches, 12 months of age and 2 m height. The experimental design was completely randomized design with four treatments and five replications. The ensiled material consisted of sorghum alone and sorghum with 15, 30 and 50% leucaena on a natural matter basis. The forage was ensiled in PVC tubes with 100 mm diameter and 500 mm length; sorghum and legumes were harvested on the same day and chopped separately, in a forage harvester, adjusted to 1 to 2 cm particle size, later weighed the appropriate proportions of each treatment, mixed and compacted in the silos with a wooden socket, taking care to obtain a density of 500 to 600 kg $m^{-}3$. Silos were closed with a PVC cap with Bunsen valves, sealed with adhesive tape. A total of 20 silos was prepared, which were opened 35 days after ensiling. Fresh material (sorghum and leucaena separated) was sampled at the time of ensiling, and the samples were placed in paper bags, weighed and dried in a forced ventilation oven with a temperature of 65° C for 72 hours to determine the chemical composition (Table 1). For taking silage samples, 5 cm of the upper and lower portions of the mass were disregarded. After this, the silage was homogenized and part was used to extract approximately 200 mL juice, with the aid of a hydraulic press, for determination of pH, with a digital pHmeter and NH_3-N, according to Bolsen et al. (1992). The water activity was determined using the Aqua Lab 4TE DUO equipment.

Part of the ensiled material, as well as the original material, was placed on a plastic tray, weighed and then pre-dried in a forced-ventilation oven at 60°C for 72 hours. The pre-dried samples were ground in a Wiley stationary mill with a 1 mm-mesh sieve, to perform the chemical analysis. Content of dry matter (DM), ash, crude protein (CP), neutral detergent fiber corrected for ash and protein (NDFcp), acid detergent fiber (ADF), lignin (LGN), non-fiber carbohydrates – (CP + EE + MM + NDFcp) and (EE) ether extract were obtained according to methodology described by Detmann et al. (2012).

Data collected were subjected to analysis of variance and, when the F-test was significant, a regression study was performed for the inclusion levels of leucaena into the silage, considering the probability level of 5%. The SISVAR software was used (Ferreira, 2011).

Results and discussion

There was no effect ($p < 0.05$) of leucaena inclusion levels for the variables pH, Aw, and total NH_3-N, which can be observed in Table 2.

Acidity is an important point in the evaluation process of silage quality, so pH values of well-preserved sorghum silages vary between 3.6 and 4.2, this means lower losses of the protein fraction (McDonald, 1981). Leucaena has a low content of soluble carbohydrates and a high buffering power promoted by residual amino acids and presence of cations, but these characteristics did not cause the increase in pH in the different levels of inclusion with a mean value of 3.74.

Table 1. Chemical composition of forages of leucaena and sorghum before ensiling, in % dry matter.

Variables	Leucena	Sorghum
Dry Matter (DM), %	33.213	37.829
Crude protein, % DM	23.617	7.215
Ether Extract, % DM	2.788	2.057
Neutral Detergent Fiber, % DM	69.193	43.566
Acid detergent fiber, % DM	45.044	31.524
Ash, % DM	8.8633	7.5176

Table 2. Values of pH, Water activity (WA) and ammonia nitrogen (NH_3-N) of sorghum silage with increasing levels of leucaena.

Parameters	Levels of leucaena, %				Mean
	0	15	30	50	
pH	3.766	3.698	3.744	3.744	Y=3.738
WA	0.959	0.959	0.953	0.955	Y=0.957
NH_3-N/total N	0.245	0.300	0.266	1.071	Y=0.258

Water activity (Aw) represents water available for microbial growth and reactions that can spoil food, its free form in materials is expressed in the scale of 0 to 1.0. Microorganisms in general are fundamental in the fermentation process of silages and have their activity largely affected by Aw, the development of most bacteria and fungi is restricted to Aw values above 0.90. In this way, it can be inferred that the fermentation was adequate, given the pH and NH_3-N values, indicating that there was no proteolysis, conferring to the preserved food a good fermentative quality.

The ammonia content of silages, expressed as a percentage of ammonia nitrogen in relation to total nitrogen (NH_3-N/TN), is used in the evaluation of silages, indicating the amount of protein degraded during the fermentation. Silage is considered to be of excellent quality when it has a NH_3-N/TN ratio of less than 10%, good, between 10 and 15%, medium, between 15 and 20% and poor, when higher than 20% (AFRC, 1987). The results obtained confirm those reported by Evangelista et al. (2005), who found a variation from 0.23 to 2.15% of Total-N, respectively, for pure sorghum silage and sorghum silage with 40% forage of leucaena, classified according to this variable as of excellent quality.

There was an increasing linear effect ($p < 0.05$) for the variables DN, CP and lignin, and a decreasing linear effect ($p < 0.05$) for NDFcp and hemicellulose, and a quadratic effect was found ($p < 0.05$) for the ash content according to leucaena inclusion levels into sorghum silage. The levels of EE, ADF and NFC were not influenced by the inclusion of leucaena into sorghum silage (Table 3).

Forage harvesting at the appropriate time of the dry matter content is essential for the production of silage with high nutritional value. Materials harvested at later maturity stages, when they contain above 35% dry matter, are able to form bags of air and favor the growth of microorganisms; in turn, materials harvested below 30% of dry matter result in low quality silage, due to undesirable fermentation (Van Soest, 1994). When compared to pure silage, the inclusion of leucaena provides an increase in dry matter. Evangelista et al. (2005) worked with the inclusion of 40% leucaena forage into sorghum silage and found lower DM values (28.4%). The highest DM values verified in this work are due to a higher inclusion of leucaena branches into the silage, besides the dry matter of the sorghum at the time of ensiling was higher. However, these values remained within the appropriate levels for good fermentation.

The CP content of the silage was high, ranging from 7.2 to 23.6% with the inclusion of leucaena, due to the higher CP content of leucaena compared to sorghum, our results are in agreement with those of Evangelista et al. (2005), who evaluated the chemical composition of the sorghum silage added with up to 40% leucaena and found that the CP content of the silage was elevated from 4.5% to 10.3% with the inclusion of the highest amount of leucaena forage, as well as Jahanzad et al. (2016), which also reported a 6% increase in CP content in millet silage with up to 60% soybean inclusion.

Regression analysis revealed a quadratic response for mineral matter in relation to leucaena content in silage. The values found are equivalent to those observed by Eichelberger, Siewerdt, and Silveira (1997), when they worked with corn silage with addition of 40 and 50% of soybean forage.

There was a decreasing linear effect ($p < 0.05$) for NDFc contents with increasing levels of leucaena forage (Table 1). The addition of 50% leucaena into sorghum silage promoted a 3.74% decrease in NDFcp content. This decrease is related to the linear reduction observed in the contents of hemicellulose, solubilized during fermentation. The decrease of 8.28% in the addition of 50% leucaena, was provided the greater inclusion of the sorghum silage, since the fresh plant had a low content of NDFcp. NDFcp contents lower than 50% are more desirable due to less participation of the less indigestible fraction, which guarantees the best use of nutrients.

Table 3. Chemical composition of sorghum silage with increasing levels of leucaena and their respective coefficients of determination (r^2).

Parameters	Levels of leucaena, %				Equation	r^2
	0	15	30	50		
Dry matter, %	33.47	33.85	34.24	34.75	$y = 33.3 + 0.025x$	88.68
crude protein, %DM	7.82	10.33	12.78	16.05	$y = 7.89 + 0.16x$	99.02
Ether extract, %DM	2.00	1.97	2.26	2.51	$y = 2.18$	-
Ash, %DM	7.74	8.20	7.45	7.60	$y = 7.7 + 0{,}10x - 0{,}006x^2$	100.00
neutral detergent fiber cp, %DM	56.65	54.51	51.68	48.37	$y = 56.66 - 0{,}165$	99.77
acid detergent fiber, %DM	32.20	34.39	34.35	34.17	$y = 33{,}03$	-
Hemicellulose, %DM	24.07	22.15	20.23	17.67	$y = 24{,}08 - 0{,}128x$	99.54
Lignin, %DM	7.29	8.08	8.87	9.93	$y = 7.3 + 0{,}05x$	95.12
non-fiber carbohydrates, %DM	25.50	25.21	26.22	25.24	$y = 25.54$	-

Differently from NDFcp, ADF content was not influenced by the inclusion of the legume ($p > 0.05$), and presented a mean value of 33.03% (Table 1). Jahanzad et al. (2016) also did not detect difference in ADF content with the inclusion of 40, 50 and 60% soybean into millet silage. In turn, Stella, Peripolli, Prates, and Barcellos (2016) reported a ADF reduction from 35.2% to 30.4% in sorghum silage, with up to 75% soybean inclusion. ADF values observed in our study are within the ideal range (Van Soest, 1994), since it is known that high contents of ADF, over 40%, are undesirable. In addition, the presence of lignocellulosic constituents, which are poorly used by the animals and negatively correlated with the dry matter degradation, may interfere with the degradation of the food by ruminal bacteria (Silva et al., 2015).

The addition of leucaena into sorghum silage resulted in a negative linear response for hemicellulose content and a positive linear response for lignin content. The increase in lignin content in relation to the inclusion of leucaena into sorghum silage can be explained by the high content of this constituent in the leucaena cell wall, as verified by Silva et al. (2015). The reduction in the hemicellulose content, which is the most degradable fraction of the fiber and the increase in the lignin content, are factors that limit the nutrient digestibility, reducing, therefore, the nutritional quality of the silage.

The inclusion of leucaena did not influence the NFC content of mixed sorghum silage ($p > 0.05$), with a mean value of 25.5% DM (Table 3). This content can be considered satisfactory, because NFC less than 10% cause a decrease in the formation of organic acids responsible for silage preservation (Ribeiro et al., 2010). Another important factor is that silages with high NFC values tend to present higher amount of starch and sugars, nutrients that are responsible for improving the energy content of food (Silva et al., 2015).

Conclusion

The inclusion of up to 50% leucaena into sorghum silage is recommended, since it maintains the fermentative quality and improves the nutritional quality of sorghum silage.

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