Scientific Paper

Effect of the inclusion of different mulberry (Morus alba) *levels on the nutritional quality of sorghum* (Sorghum almum) *silages*

A. Alpízar[1]; María Isabel Camacho[1]; Carlos Sáenz[1], Manuel E. Campos[2], Javier Arece[3] and Marcos Esperance[3]

[1]*Escuela de Ciencias Agrarias, Facultad de Ciencias de la Tierra y el Mar, Universidad Nacional de Costa Rica, Heredia, Costa Rica, apartado postal 86-300*
E-mail: andres.alpizar.naranjo@una.cr
[2]*Universidad Técnica Nacional, Sede de Atenas, Alajuela, Costa Rica, Apartado postal 7-4013*
[3]*Estación Experimental de Pastos y Forrajes "Indio Hatuey". Central España Republicana, CP 44280, Matanzas, Cuba*

ABSTRACT: The objective of this study was to determine the effect of the inclusion of different mulberry (*Morus alba*) levels on the nutritional quality of sorghum (*Sorghum almum*) silages. Five sorghum:mulberry ratios ((100:0, 75:25, 50:50, 25:75 and 0:100) were evaluated, with a completely randomized design and three replications per treatment. The mixtures were made on fresh basis and they were placed in 120-L plastic tanks. Compaction was performed in 20-cm layers, tamping the materials down with the feet, and molasses was added at a rate of 4 % of the weight of the green material. The silages were stored during 40 days. Dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose and ash were determined before and after conservation. With the increase of the mulberry percentage the DM, CP and ash contents increased significantly ($p < 0,05$). The NDF, ADF and hemicellulose tended to increase after conservation. The pH values of the mixtures 100:0 (3,81), 75:25 (3,91) and 50:50 (3,89) had significant differences ($p < 0,01$) with regards to 75:25 (4,05) and 0:100 (4,08). The organoleptic evaluation showed an adequate conservation process in all the mixtures. The inclusion of 50 % mulberry is concluded to constitute a viable alternative to improve the nutritional quality of the sorghum silage.

Key words: animal feeding, chemical composition, silos

INTRODUCTION

One of the problems of ruminant feeding in the tropics is the poor nutritional quality of forages, which is mainly due to their low nitrogen contents and the reduction of their productions during the dry season (Cárdenas *et al*., 2003). To prevent these insufficiencies, livestock production is forced to use high-price balanced supplements, which represent between 56 and 60 % of the total costs of cattle milk production in Costa Rica (Tobía *et al*., 2004).

This situation induces the search for technological alternatives to reduce costs and increase the efficiency of livestock production systems. One of them is silage elaboration; which allows, without causing large transformations in nutritional quality, to preserve the forage excess produced during the rainy season to be used in the season of lower availability (Tobía *et al*., 2004; Borja *et al*., 2012).

In Costa Rica sorghum shows a yield of 40,2 t of GM/ha^{-1}/cutting^{-1} and it is ideal to be preserved, due to its high concentration of soluble sugars; although its nutritional quality is limited by its low protein content (Elizondo, 2004; Vargas, 2005).

Mulberry is a tree with high nutritional value. Its crude protein values place it as a viable alternative to be used in ruminant feeding, fresh or ensiled (Ojeda and Montejo, 2001; Casanovas *et al*., 2004; Martín *et al*., 2007; Milera *et al*., 2010).

Ojeda *et al*. (2006) consider that the elaboration of mixed silages has the advantage of utilizing, simultaneously, the yields and fermentative potential of grasses, together with the higher protein levels shown by trees; these aspects allow to obtain higher-quality silage.

In that sense, the objective of this study was to determine the effect of the inclusion of different mulberry levels on the nutritional quality of sorghum silages.

MATERIALS AND METHODS

Location and climate. The study was conducted during the rainy season (May and July) in the experimental farm Santa Lucía (EFSL) of the School of Agricultural Sciences of the National University of Costa Rica, which is located at 10º 1' 20'' of North latitude and 84º 06' 45'' of West longitude, at an altitude of 1 250 m.a.s.l., in the Barva canton (Heredia province, Costa Rica).

The climate of the experimental zone shows an annual rainfall of 2 371 mm. The relative humidity is 78,0 % and the mean annual temperature, 21,5 ºC, with minimum of 15,2 ºC and maximum of 27,80 ºC (IMN, 2009).

Agronomic management of the forages. The sorghum plantation was drill sown, at a distance of 1,0 m between rows, with a dose of 20 kg/ha.

The forages were fertilized on three occasions: at the moment of sowing, with NPK formula (10-30-10) at a rate of 60 kg/ha; and 20 and 40 days after sowing –respectively–, with urea at a rate of 33,2 kg/ha.

The undesired plants were locally controlled through the application of selective herbicide 2,4-D and glyphosate, in a localized way. The forage was harvested at the beginning of flowering, which occurred 70 days after sowing.

The mulberry plantation had four years of establishment, and had a planting density of 25 000 plants/ha. At the start of the rainy season (May) a homogenization cutting was performed and it was fertilized with the same NPK formula; although it was reinforced with ammonium nitrate and potassium sulfate in a proportion of 30-50-15, at a rate of 20 g/plant. The forage of this plant (leaves and stems) was harvested 90 days after regrowth, at a cutting height of 40 cm.

Treatments and experimental design. The design was completely randomized, with five treatments and three repetitions (table 1).

Table 1. Proportion of sorghum and mulberry in each treatment.

Treatment	Sorghum	Mulberry
T_1	100	0
T_2	75	25
T_3	50	50
T_4	25	75
T_5	0	100

Experimental procedure and measurements. The silos used were plastic tanks with airtight closing, with an average empty weight of 5,68 ± 0,36 kg and a capacity between 70 and 82 kg of fresh forage.

The sorghum and mulberry forages were separately chopped, with an average particle size of 2 cm. The experimental mixtures of sorghum and mulberry were made on fresh basis, and molasses was added at a rate of 4 % of the weight of the green material; compaction was done in 20-cm layers, packing the material down with the feet. Afterwards, the silos were airtightly sealed and opening was prefixed for 40 days later.

The nutritional composition of the different mixtures was determined, in fresh, during silage elaboration; while the material preserved until opening was sampled by means of a cylindrical bore, of 2 m of length and 5 cm of diameter. This procedure allowed to obtain ensiled materials at different depths (0-20, 40-50 y 100-120 cm), which were homogenized to form samples of 0,6 kg.

The measured indicators were: dry matter (DM), crude protein (CP) and ash (AOAC, 1984). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and hemicellulose were determined according to the procedures proposed by Goering and Van Soest (1970).

The fermentative quality of the silages was determined from the acidity degree (pH), according to the methodology described by Barnet (1954); and the organoleptic evaluation, according to the table of indicators proposed by Ojeda *et al*. (1991).

Statistical analysis. A variance analysis was made through the general linear model. The means were compared by Duncan's (1955) multiple range comparison test, for a significance level of $p < 0,05$. The statistical pack SPSS®, version 15.0, was used.

RESULTS AND DISCUSSION

The DM content is important during the ensiling process, because it acts as a controller of the fermentative process quality (García *et al*., 2010). In this sense, Romero and Aronna (2006) stated that with the increase of the forage DM the level of effluents is reduced, which can generate the loss of soluble nutrients.

The DM values of the sorghum:mulberry green forage mixtures varied from 26,52 % in sorghum alone to 31,71 % in the treatment of 100 % mulberry, with significant increases ($p \leq 0,05$) as mulberry increased (table 2). This trend was maintained once the conservation process was over, although with lower values with regards to the initial ones, which is ascribed to the incorporation of molasses.

Boschini (2003) found similar performances when evaluating different proportions of corn and mulberry, which ratifies that changes occur in DM during conservation (Ojeda *et al*., 2006).

Table 2. Chemical composition of the ensiled material at the beginning and end of the trial.

Indicator	Treatment (sorghum:mulberry ratio)					
	T_1 (100:0)	T_2 (75:25)	T_3 (50:50)	T_4 (25:75)	T_5 (0:100)	SE ±
			DM			
Initial	26,52[e]	28,96[d]	29,36[c]	30,26[b]	31,71[a]	0,45
Final	24,84[d]	25,74[c]	27,57[b]	28,30[b]	29,63[a]	0,47
			CP (%)			
Initial	8,77[e]	10,47[d]	11,19[c]	11,51[b]	11,76[a]	0,28
Final	7,92[d]	8,32[cd]	8,92[c]	9,67[b]	10,42[a]	0,25
			NDF			
Initial	54,88[a]	48,91[b]	47,17[c]	41,15[d]	41,32[d]	1,37
Final	60,70[a]	50,42[b]	47,08[c]	44,57[c]	41,21[d]	1,81
			ADF			
Initial	35,08[a]	27,42[c]	28,33[b]	24,87[e]	26,43[d]	0,94
Final	36,49[a]	31,59[b]	26,73[c]	27,48[c]	25,94[c]	1,10
			Hemicellulose			
Initial	19,80[b]	21,50[a]	18,85[c]	16,28[d]	14,90[e]	0,63
Final	24,21[a]	18,83[bc]	20,35[b]	17,09[cd]	15,27[d]	0,87
			Ash			
Initial	8,29[e]	10,55[d]	11,18[c]	11,99[b]	13,10[a]	0,42
Final	9,01[c]	10,25[b]	10,34[b]	11,19[b]	12,92[a]	0,36

a, b, c, d, e: means with different letters in the rows significantly differ for $p \leq 0{,}05$ (Duncan, 1955).

In this study, good-quality silage was obtained, although the initial and final DM contents were lower than the ones reported by McDonald *et al.* (1998), who consider that the optimum DM values to guarantee this purpose should fluctuate between 32 % and 37 %.

The crude protein of the fresh and ensiled forages showed significant increases ($p \leq 0{,}05$) as the mulberry percentage in the mixtures increased, which was also reported by Ojeda *et al.* (2006) and by Cárdenas *et al.* (2003), when introducing increasing levels of tree species in grass silages.

Mulberry reached CP values similar to those reported by González (1996). The conservation process caused decrease in such values, which is ascribed to the proteolysis that occurs during fermentation, with the subsequent transformation of protein into non-protein nitrogen, mainly as ammonia (Cárdenas *et al*., 2004).

The forages used showed differences regarding the fiber-related components. Sorghum had higher NDF, ADF and hemicellulose percentages than mulberry, for which these indicators tended to decrease significantly ($p \leq 0{,}05$) as the mulberry percentages increased.

After conservation, these indicators tended to increase their percentage, which is ascribed to the participation of some of their components in the fermentative processes; such actions cause their proportions to vary, as compared with fresh forages (Vargas, 2005).

These results in the fibrous components did not have the same performance during conservation in other grasses. In this sense, the NDF values obtained in sorghum and mulberry were lower than those reported by Amador and Boschini (2000) and Boschini (2000).

On the other hand, Boschini (2003), when evaluating mixed silages of corn and mulberry, found an increase in the NDF contents and a decrease of ADF and hemicellulose, as a consequence of the fermentation process.

Likewise, the ADF decreased with the increase of mulberry in the mixture, which is ascribed to the presence of higher ADF contents in sorghum (Boschini and Elizondo, 2005). In this study the ADF value shown in treatment 1 (100 % sorghum) was similar to the one reported by Calsamiglia *et al.* (2004).

The ash content of the green and preserved forages tended to increase significantly ($p \leq 0{,}05$), in agreement with the increase of the mulberry level, which is ascribed to its high calcium levels (Boschini and Vargas, 2009).

During the conservation process transformations occur that define its fermentative quality, and pH is considered to be one of the most radical changes (Vallejo, 1995). In this sense, Ojeda *et al.* (2006) stated that when silage shows between 25 and 30 % of DM and its pH is lower than 4,3 it can be considered that the process developed in a satisfactory way.

The pH values of the mixtures, up to the 50:50 ratio, did not show significant differences ($p < 0{,}01$) with regards to the silages of 100 % sorghum. However, with the increase of the mulberry inclusion percentage this indicator increased significantly (fig. 1).

These changes seem to be related to the increases shown by trees in the buffering capacity, with regards to grasses (Santana, 2000). Nevertheless, the results indicate that mulberry has fermentative qualities that allow it to be preserved alone, because, even in the highest proportions, its pH values do not compromise the silage stability (Mangado, 2006).

On the other hand, organoleptic indicators constitute a subjective evaluation of silage quality through the senses, and have become the most widely used and practical evaluation alternative (Ojeda *et al.*, 1991).

The silages showed a nice smell to ripe fruit, as well as a yellowish green color for mixtures 100:0, 75:25 and 0:100 and brown green for 50:50 and 25:75; the texture was well defined, with easy separation in all the silos (table 3).

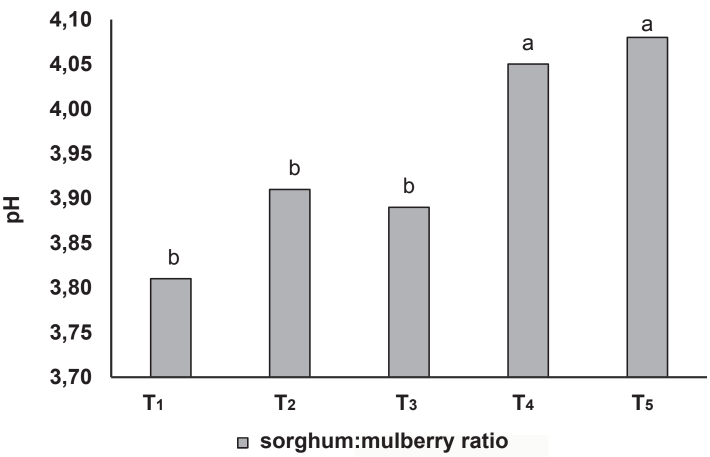
The ensiled mixtures had percentages from 92 to 100 %, which is considered optimal for good-quality silages (Vallejo, 1995).

The objective of conservation is to preserve the nutritional characteristics of the original forage, with minimum changes in the DM and nutrient contents (Muck, 1998). In this sense, the ensiled mixtures only showed small changes in the nutritional indicators evaluated, which indicates that an adequate fermentation process occurred.

The incorporation of mulberry in the sorghum silage increased its nutritional value, because it improved the protein contents and decreased the fibrous components. The inclusion of 50 % mulberry was the best result, because crude protein increased in the sorghum silage, fiber decreased and an adequate pH to preserve the material was reached.

ACKNOWLEDGEMENTS

The authors thank the Foundation for the Encouragement and Promotion of Research and Transference of Agricultural Technology of Costa Rica (FITTACORI), for the funds granted to conduct this research.



a, b: means that differ significantly for $p \leq 0{,}01$

Fig.1. pH of the ensiled samples

Table 3. Evaluation of the organoleptic characteristics of the ensiled mixtures of sorghum and mulberry.

Indicator	Description	%	Ratio (%)				
			100:0	75:25	50:50	25:75	0:100
Smell	Nice	54	54	54	54	54	54
	Little nice	36					
	Unpleasant	18					
Color	Yellowish green, green, light green	24	24	24	16	16	24
	Brown green, dark green, reddish green	16					
	Yellowish brown, dark coffee, greenish coffee	8					
Texture	Well defined, easy to separate	22	22	22	22	22	22
	Soapy to the touch, ill defined	11					
Total percentage			100	100	92	92	100

Received: April, 25, 2013

Accepted: December 12, 2013