Chemical composition and *in situ* ruminal disappearance of sorghum silages grown in the mexican humid tropic

Composición química y degradabilidad ruminal *in situ* de ensilados de sorgo cultivados en el trópico húmedo mexicano

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Abstract

The purpose was to evaluate the chemical composition and *in situ* ruminal dry matter disappearance of four types of grain sorghum silages, one brown midrib sorghum (bmr) and, a corn silage, grown under rainfed conditions in a humid tropical region of Mexico. The crops were established at three sites. At harvest, three minisilos per treatment were filled with forage previously chopped. Minisilos opened at 55 days and samples of silage taken to dry and ground to 1 mm to determine the chemical composition and *in situ* ruminal dry matter disappearance. The crude protein was higher ($p<0.05$) in sorghum silages than corn silage. In sorghum silages, bmr sorghum had the lowest ($p<0.05$) cell wall content, and was equal ($p>0.05$) in ADF and ADL to corn silage. The degradation parameters (*a, b, c*) was higher ($p<0.05$) in bmr sorghum silage than grain sorghum silages. The effective degradability was equal ($p>0.05$) in bmr sorghum and corn silages. In the humid tropics, bmr sorghum silages are a good alternative to corn silage, especially in the dry season.

Keywords

Sorghum bicolor • silages • digestibility • forage quality • grasses • dry season

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Resumen

El objetivo fue evaluar la composición química y la degradabilidad ruminal *in situ* del ensilado de cuatro híbridos de sorgo para grano, uno de nervadura café (bmr) y un híbrido de maíz, bajo condiciones de secano en una región del trópico húmedo de México. Los cultivares se establecieron en tres sitios. A la cosecha, en cada sitio se llenaron tres minisilos de laboratorio por tratamiento. Los minisilos se abrieron a los 55 días y se tomó una muestra que fue secada y molida a 1 mm para determinar la composición química y la degradabilidad ruminal *in situ* de la materia seca. La proteína cruda fue mayor ($p<0,05$) en los ensilados de sorgo que en el ensilado de maíz. Entre los sorgos, el sorgo bmr presentó el menor ($p<0,05$) contenido de pared celular y fue similar ($p>0,05$) en FDA y LDA al ensilado de maíz. Los parámetros de degradación (*a, b, c*) fueron mayores ($p<0,05$) en el ensilado de sorgo bmr en comparación al de sorgos para grano. La degradabilidad efectiva fue igual ($p>0,05$) en el ensilado de sorgo bmr y el maíz. En el trópico húmedo, el ensilado de sorgo bmr, es una alternativa viable con referencia al ensilado de maíz, especialmente en la época seca.

Palabras clave

Sorghum bicolor • ensilado • digestibilidad • calidad del forraje • pastos • época seca

Introduction

The low quality and availability of pastures, especially in the dry season (January-May), is a recurrent problem in the humid tropical regions of Mexico (1). That reduces the intake of nutrients in the dual-purpose cattle (DPC) system and negatively influences animal performance. The 70% of producers with DPC consider the seasonal production forage as the main limitation of animal performance (1). Other factor that limits the availability of nutrients in tro pical grasses is the high lignin content, which can represent up to 10.5% of DM (28). Lignin is the primary indigestible component in plants cell walls that inhibits bacterial digestion in the rumen of fibrous carbohydrates (4).

In the tropics of Mexico, the conservation of forages as silage is promoted as an alternative to increase and maintain milk production in the year. Corn (*Zea mays* L.) is the crops to choice for producing high quality silages (22, 25); but this crop exhibits drawbacks during periods of water stress (6, 18). Under this scenario, sorghum [*Sorghum bicolor* (L.) Moench] is used as alternative crop to replaced corn silage, because can be sown late, is better in water use efficient, have high biomass yields (15, 21), increases the soil cover and has a lower nutrients and pesticides requirement compared with corn crop. Sorghum silage has acceptable levels of soluble carbohydrates (60-80 g kg^{-1} of DM), relatively low buffer capacity, dry matter content of more than 20% and physical structure to compact during silo filling and, represents lower production costs compared to corn (15, 27).

Sorghum silages is less used than corn silages, because sorghum exhibit higher lignin content and lower fiber digestibility, which increases rumen filling, reduces DMI and limits milk yield. In the other hand, brown midrib (bmr) sorghums have lower lignin compared with conventional sorghums (without bmr gene), which makes them more digestible. Studies of *in situ, in vitro* and *in vivo* digestion, show that forage of plants with the bmr mutation, possess greater dry matter and NDF digestibility than its counterparts (3, 13, 21). Also, studies showed that bmr sorgos silage can equal the nutritional value of conventional corn silage, supporting similar milk yield (4, 21).

In central and northern of Mexico, sorghum silage is considered as an alternative to corn silage for cattle milk production. For high yields of dry matter (18 t ha^{-1}), digestibility (56%) and net energy lactation (1.45 Mcal kg^{-1}), sorghum silage is widely used by milk producers in these areas of country (20). However, under the environmental conditions of the tropics, the agronomic behavior of this forage species is different.

Overtime, selection of sorghum varieties originated plants with different morphological characteristics (26), among these, varieties with higher proportion of grain and lower proportion of stems. These characteristics can result in silage with high-energy value content, which can be used efficiently as a supplement in rations of DPC in the tropics to increase milk production throughout of year. However, there is no information about the behavior of sorghum in terms of silage yields and quality, produced in rainfed conditions, particularly in the dry season of the year (January-May).

Objective

Assess forage yield, chemical composition and *in situ* dry matter disappearance in different sorghums and corn silages cultivated under typical conditions of the humid tropics in Mexico.

Materials and methods

In December 2012, the grain type sorghums DK-67 (DK67, Dekalb®), Niquel (Niquel, Asgrow®), RB-Norteño (RBN, Inifap) and RB-Huasteco (RBH, Inifap), the two first adapted to the area and the two seconds non-adapted (from Tamaulipas state), a forage sorghum type gene-brown midrib Silo Miel 350 (SM350, Genex®) and a corn hybrid A7573 (A7573, Asgrow®), traditional in the zone, were established under rainfed conditions in three sites of Loma Bonita, Oaxaca, Mexico. The sites are located at coordinates 18°05' L N, 95°53' L W; 18°08' L N, 95°53' L W; 18°08' L N, 95°53' L W, between 0 and 200 m a. s. l. The soils in the three sites have a texture of crumbly sand, sandy clay loam and sandy loam; with 8, 51, 51 ppm of inorganic nitrogen; 52, 5.8 and 11 ppm of phosphorus; 3.68, 4.62 and 4.45 pH, respectively. The dominant climate in the area is warm humid with rains (81.7%) in summer (14). The average annual temperature is 25°C; maximum of 39°C and a minimum of 16°C and, 1,800 mm rain precipitation.

After weeding grass and two harrowing steps, sowing was done with a traditional zero- tillage machine at 20 kg ha^{-1} seed density. From each material, eight lines of twenty meters were planted with 0.75 m of space between lines, leaving a useful plot of 120 m^2. Fertilization was done manually, by apply 3 kg of urea (46-00-00) and 2 kg of di-ammonium phosphate (DAP, 18-46-00) per useful plot, equivalent to 417 kg ha^{-1} of fertilizer (60% urea and 40% DAP; 145 kg of N and 77.0 kg of P_2O_5 ha^{-1}), in two applications: at 15 and 50 days after the sowing date. The crops tillage were the traditional: two foliar applications, insecticide and manual weeding.

The crops were harvested manually when the plant reached the milky-dough grain maturity stage (86 ± 5 d) and corn, when the grain reaches the half milk line (90 ± 3 d post-sowing). To the harvest, in each plot, the number of plants in 2.5 m per line were counted, cutting and weighed. Plant samples were taken diagonally in the lines until completing one line. With this information, the final density of plants, yield green forage and dry matter forage were calculated.

These plant samples were chopped with a gasoline stationary forage chopper. A sample of green material was taken and was frozen for further analysis. With the remaining material, three laboratory minisilos with a capacity of approximately three kilograms of green forage were filled. The minisilos were made of PVC with measures of 15.7" high x 4" diameter; with lower drainage for liquid and upper outlet for gases. After 55 days the minisilos were opened, the pH was measured and, approximately one kilogram of samples were taken and these were frozen for further analysis. Three replicates were made to measure the pH, by mixing in a blender jar for domestic use, 25 g of silage plus 250 ml distilled water, the mixture was liquefied for 30 seconds at maximum speed.

The solution was filtered through two layers of cheese cloth, after five minutes the measurement was made using HANNA potentiometer, model pH 209 (Instruments Inc. USA).

Chemical analysis of the samples

Fifty-four silage samples (nine per treatment) and eight-teen green forage (three per treatment) were unfreeze at room temperature and dry in triplicate in air oven at 60°C for 48 h; then, they was ground to 1 mm (Thomas A. Wiley Laboratory Mill, Model 4, Thomas Scientific, Swedesboro, NJ). The absolute dry matter (105°C for 8 h in oven), ash (550°C for 3 h in a muffle furnace) and crude protein (N x 6.25) were determined in the milled samples (2). The content of neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) was determined sequentially in the ANKOM^{200} Fiber Analyzer, using Ankom® F57 filter bags with a pore size of 25 μm.

In situ dry matter disappearance test

This test was only done in Niquel, DK67, SM350 and A7573 silages. The preparation of subsamples was as follows: from each of the nine silage samples, 25 g were taken to form a representative subsample of each silage, which were used for the ruminal degradability test. These silages were selected for having presented better chemical composition, based on NDF, ADF and ADL content.

Two heifers of Beefmaster breed, with age of 26 months and average live weight of 450 kg, with permanent rumen cannula were used. One week before the incubation of the samples, each heifer received 8.8 kg daily (on dry basis) of a diet based on alfalfa (*Medicago sativa*) hay (32.4%), pangola (*Digitaria decumbens*) grass hay (35.0%), molasses (6.0%), salt (0.9%), minerals (0.4%) and commercial supplement (25.2%), which contained 12.3, 42.0 and 10.4% PC, NDF and ash, respectively.

The nylon bag technique (23) was used. In bags of 5 x 10 cm and pore size of 50 microns (Ankom Corp., Fairport, NY), were deposited 3 g of dry sample ground at 1 mm; two bags were used for each treatment and each incubation time, for a total of 48 bags per heifer. The incubation times were: 6, 12, 24, 48 and 72 h. Bags were introduced into the rumen reverse manner, that is, the first time 72 h, ending with time 6 h.

In each incubation time, a bag without sample (white) was included to use it as a correction factor. The determination of soluble material at time zero, was done by immersing these bags group in distilled water at 39°C for 15 minutes.

After 72 h incubation bags were taken out of rumen at same time and placed in ice water to stop microbial activity. Afterwards, the bags were transferred to laboratory, where one by one these were washed manually with tap water until the water is clear. Bags were then dry in forced air oven at 65°C for 48 h to obtain the dry matter disappearance.

The rumen degradation parameters of dry matter (DMD) were estimated using the equation:

$$\% \text{ degradability} = \frac{Initial\ weight\ (g) - residual\ weight\ (g)\ x\ 100}{Initial\ weight\ (g)}$$

The DMD parameters were adjusted using the model described by Ørskov and Mc Donald (1979):

$$\mathbf{P\ (t) = a + b\ (1 - exp\ (-c * t))}$$

where:

P = amount of sample or nutrients that disappear from the bag after a time t of permanence in the rumen.

a = soluble fraction that quickly escapes from the bag and is assumed to be completely degradable.

b = nutrient fraction insoluble, but potentially digestible by the rumen microorganisms.

c = degradation rate (% h^{-1}) of fraction b.

a + b = potential degradability (PD) of the substrate after 72 h incubation.

1 - (a + b) = represents the indigestible fraction (IF) of the sample.

The effective degradability (ED) in percent, which define as the material that is actually degraded by the rumen microorganisms, was calculated by the equation:

$$\mathbf{ED\ (\%) = a + [(b * c) / (c + k)]}$$

where:

a, b, and c = previously defined in the previous equation.

k = flow rate of the rumen particles, established at 2.0 and 5.0% h^{-1} for this study; low and medium milk production, respectively (18).

Statistic analysis

The yield and chemical composition data of the forage were analyzed with the MIXED procedure of SAS 9.1 (29) based on a complete randomized block design; considering the site effect and the interaction site with species as random and the effect of variety or hybrid as fixed.

The comparison of means was made with the least significant difference (LSD), declaring statistical difference when p≤0.05 and tendency between p=0.051-0.100.

The estimation of degradation kinetics parameters was made using the iterative process of the Gauss Newton algorithm, with the NLIN procedure of the statistical package SAS 9.1 (29).

The variables were subjected to an analysis of variance with PROC GLM and comparing means of the parameters obtained for each treatment was done with the Tukey test, declaring statistical difference when p≤0.05 and tendency between p=0.051-0.100.

Results and discussion

Climatic characteristics

In crop development (December 1, 2012 to March 16, 2013; figure 1), the average temperature, relative humidity and cumulative rainfall were 23.2°C, 84.1% and 103.5 mm, respectively. The rainfall was less than 300 mm required by the crop for optimal development; therefore, the potential of the plant to produce biomass could be limited.

There are two critical periods where the crop requires moisture in the soil, the first is between 20 to 25 d post-emergence and the second in the flowering stage (2). Even in this study accumulated rainfall was not optimal, figure 1 shows greater rainfall (47.2%) occurred in February; at the beginning of the flowering stage (62 ± 3 d post-sowing). This contributed to an acceptable panicle development and grain filling in all sorghums.

On the other hand, the corn hybrid A7573 presented small ears, with small grains, this as a result of a higher water stress that crop presented, since it is a species that demands more water (30 to 40% more than sorghum).

Plant density and dry matter yield

The final plants density per hectare presented variation due to the genotype (p=0.0012); however, this variation was due to the corn genotype A7573 which presented 61,778 plants ha^{-1}. Among the sorghums, no statistical difference was observed in density, with average of 305,139 plants ha^{-1}, but numerically sorghum DK67 had the highest density (350,972) and sorghum SM350 had the lowest (267,972 plants ha^{-1}).

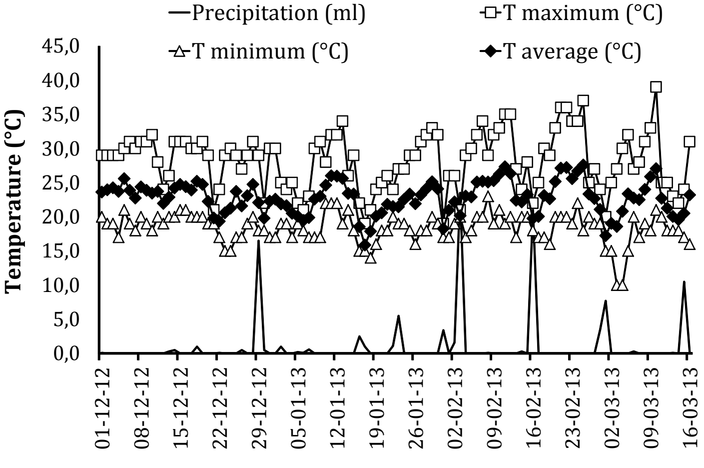

Figure 1. Precipitation and temperatures occurred during the period of crops development in study area.

Figura 1. Precipitación y temperaturas ocurridas durante el periodo de desarrollo de los cultivos en el área de estudio.

At harvest, DM percent was different between treatments ($p \leq 0.05$). Grain sorghums presented an average of 27.4%, sorghum SM350 was medium and corn A7573 the lowest level; however, the RBH, SM350 and A7573 materials were statistically equal (table 1).

For the yield of DM ha^{-1}, statistical difference ($p=0.0142$) was observed between grain sorghums types, bmr SM350 sorghum and corn A7573. At harvest (cut), DM yield in sorghums ranged from 7.2 ± 3.8 to 11.5 ± 2.6 t ha^{-1}. Highest yield was with sorghum DK67 and lowest with SM350, while corn yields 10.6 ± 2.5 t ha^{-1}. The DM yield of silage presented the same behavior among the materials (table 1).

Regarding DM losses during the silage process, these were higher in grain sorghums with average of 7.4%; bmr SM350 lost 2.1%; while corn silage A7573 yielded 5.5% less DM than when freshly harvested.

The forage yield has a relationship to DM content of plant, plant density and plant height. DK67 and Niquel sorghums, due to their higher DM content, high plant density ha^{-1} and plant height, show higher forage yield, medium for corn A7573 and, lower for RBH, RBN and SM350, the latter due to its lower DM content, but also due to the low density and height of the plant (table 1).

The sorghum SM350, had the lowest DM content (24.8 ± 2%). Several studies have reported that bmr sorghums tend to have low DM yields.

The bmr gene present in these sorghums can be the cause of low forage yields in comparison with conventional sorghums (without bmr mutation) (16).

Also, the forage yield is in function of maturity stage at cutting. According to the literature, an average of 14 t ha^{-1} of DM (9.0 to 15.0 t ha^{-1}) is accepted for sorghum harvested in dough grain stage (31). The yields obtained in this study (table 1) coincide with the 11.0 t of DM ha^{-1} (24) and the 11.5 t (27) for conventional sorghum hybrids. In other studies, was reported 16.3 (4) and 14.6 t ha^{-1} (21), values higher than those observed in this study.

However, in these studies, the harvest was made in a more advanced maturity stage (dough grain), with 30.6% DM, higher than the 27.0% observed in this study, which may explain the higher yields obtained in those studies.

Table 1. Means (±SD) of dry matter content and forage yield of cultivars.

Tabla 1. Medias (±DE) del contenido de materia seca y rendimiento de forraje de los cultivos.

Cultivar	DM content at cutting (%)	Forage yield (t ha^{-1} of DM)	
		At cutting	Silage
DK67 (grain)	27.7 ± 0.4 ^{a}	11.5 ± 2.6 ^{a}	10.6 ± 2.4 ^{a}
Niquel (grain)	27.5 ± 0.4 ^{a}	11.3 ± 3.5 ^{a}	10.5 ± 3.4 ^{a}
RBH (grain)	26.7 ± 2.0^{ab}	7.3 ± 3.4 ^{c}	6.8 ± 2.8 ^{b}
RBN (grain)	27.7 ± 0.3 ^{a}	7.8 ± 2.1^{bc}	7.2 ± 2.1 ^{b}
SM350 (bmr)	24.8 ± 2.4 ^{b}	7.2 ± 3.8 ^{c}	7.1 ±3.9 ^{b}
A7573 (corn)	26.7 ± 1.5^{ab}	10.6 ± 2.5^{ab}	10.0 ± 2.5^{a}

abc = Means with the same letter in the same column, are not different ($p \leq 0.05$).

abc = Medias con la misma letra en una misma columna, no son diferentes (p≤0,05).

Is important to pointing the following, forages have a wide variation in DM yield when are grown under rainfed conditions; therefore, yields are expected to be different from one crop cycle to another, which is mainly due to the amount and distribution of rainwater throughout the plant's development period.

Regarding the yield of silage, normally in a well prepared silo losses of 5 to 10% of DM occur. In this study, the losses did not exceed 8% (table 1, page 359), which describes the good process followed in the preparation of the silage; in addition to more controlled conditions by the use of minisilos. Thus, the greatest loss occurred in sorghums silages for grain, medium in corn silage A7573 and very low in sorghum SM350 which, with respect to green material, only lost 2.1% in the silage process. This last observation may be another quality that present these sorghums when are used as silage.

Silage pH

During silage process, is important that anaerobic fermentation is reached in a short time to produce the necessary organic acids to increase the acidity to the point that eliminates undesirable microbes and preserve the ensiled material, lactic acid contributes more to the decrease pH in the silo (32). In this study, the pH was equal (p>0.05) among silages with an average of 3.6 (table 2), adequate value (27), especially with the use of minisilos.

The average pH of 3.6 obtained in this study was associated with high content of sugar in the forages, mainly starch; explained by the amount of grain present in plant, as well as the conditions controlled by the use of minisilos.

Should be noted that in the final stage of the harvest, sorghums were attacked by birds, with sorghum DK67 being the most affected; this may explain the slight increase in pH observed in this silage, due to the fact that it had a lower amount of fermentable carbohydrates for the production of lactic acid. The average pH of 3.6 is in according with that of 3.9 reported in the literature (4, 9, 21).

Crude protein (CP)

Silage material showed effect (p=0.0032) in CP content (table 2).

The sorghums silage Niquel, RBH, RBN and SM350, were equal in CP (10.6%), while sorghum DK67 and corn A7573 silages had the lowest levels (8.4% of DM).

Table 2. Means (±SD) of pH and chemical composition of silages.

Tabla 2. Medias (±DE) del pH y composición química de los ensilados.

Cultivar	pH	Chemical composition of silages			
		% CP	% NDF	% ADF	% ADL
DK67 (grain)	3.7	8.4 ± 0.8[b]	56.2 ± 4.4[a]	33.5 ± 3.1[a]	2.9 ± 0.2[a]
Niquel (grain)	3.6	10.1 ± 1.1[a]	55.5 ± 2.5[a]	33.4 ± 2.8[a]	3.1 ± 0.3[a]
RBH (grain)	3.6	10.5 ± 0.9[a]	54.9 ± 2.7[a]	32.3 ± 2.1[a]	3.1 ± 0.3[a]
RBN (grain)	3.6	11.2 ± 1.1[a]	54.7 ± 1.9[a]	32.1 ± 1.7[a]	2.9 ± 0.2[a]
SM350 (bmr)	3.6	10.6 ± 1.1[a]	45.7 ± 4.3[b]	26.3 ± 2.2[b]	2.2 ± 0.1[b]
A7573 (corn)	3.6	8.5 ± 0.9[b]	51.4 ± 3.0[a]	28.7 ± 1.6[b]	1.9 ± 0.3[b]

ab = Means with the same letter in the same column, are not different (p≤0.05).

ab = Medias con la misma letra en la misma columna, no son diferentes (p≤0,05).

In general, the CP in sorghum silage was higher that other studies, with 9.1 (19) and 9.9% (11), at a level of 28.8 and 27.5% of DM in plant, respectively. Other studies 6.8 (4) and 7.3% (21), at a 30.6% DM and, 8.7 (6) and 8.9% (7) at 32 and 30% of DM in the plant, respectively. These differences in CP content can relate to the percentage of DM content in plant at harvest. On the other hand, the lower content of CP (8.4%) observed in sorghum DK67, could be due to a smaller amount of grain, consequence of the attack of birds. Regarding the corn silage A7573, it showed a CP content according to that reported in the literature (4, 19, 21), a value lower than the rest of the sorghums with the exception of DK67.

The higher concentration of CP present in sorghum silage may be due to the level nitrogen (N) fertilization used. A study reported that above 66,700 plants ha^{-1}, the level N fertilization had significant effect on the CP concentration, with 0.3 units or 4.2% increase (16).

In this research, N fertilization level was 145 kg and phosphorus 77.0 kg ha^{-1}. Higher concentrations are recommended (10) to produce sorghum forages in the tropics; they recommend 200 to 300 kg urea and 100 to 150 kg tripe superphosphate (SFT), equivalent to 92 to 138 and 46 to 69 kg of N and P_2O_5.

Neutral detergent fiber (NDF)

There was a genotype effect ($p<0.05$) on the NDF content. The NDF was similar between grain sorghums silage and corn silage A7573 ($p>0.05$), while silage bmr SM350 had the lowest value (table 2, page 360). Although corn silage A7573 presented intermediate NDF value, statistically it was not different from grain sorghum silages.

The lowest NDF value of SM350 silage was attributed to the lower lignin content, distinctive characteristics present in these sorghum varieties.

Grain sorghums silages presented on average 55.3% of NDF, less than 57.0, 60.7 and 58.1% reported in other studies (11, 19, 21), respectively, but higher than 51.7% observed in other research (4).

The silage bmr SM350 presented 4.7 and 4.5 units less NDF compared to that observed in the literature (4, 21), but was similar to 44.9 and 46.3% reported in other study (22) for sorghum bmr-6 and bmr-12, respectively. In a more recent study (7), with a variety of sorghum for grain, reported an average of 50.7% of NDF in three years of evaluation without observing difference by year effect. For their part (16), they reported 46.6, 50.4 and 50.3% for a variety of corn, a conventional forage sorghum and a bmr sorghum, respectively; where the bmr sorghum presented the highest ($p<0.05$) NDF digestibility.

In this study, a positive relationship between plant density ha^{-1} and NDF content was observed; however, in other works (7, 16), no effect of plant density on the NDF content was detected. Perhaps at higher densities of plants ha^{-1}, as in this study, a significant effect on this variable may occur.

Acid detergent fiber (ADF)

There was a genotype effect on ADF content (table 2, page 360). Grain sorghum silages (DK67, Niquel, RBH and RBN) had similar ADF, with average of 32.8% (table 2, page 360). The sorghum SM350 and corn A7573 silages had the lowest content of ADF, but were equal to each other ($p=0.0945$).

The sorghum SM350 bmr silage presented 24.7 and 9.1% less ADF than the average of grain sorghums and corn silages, respectively. This last observation implies that this type of sorghum (bmr) can equal or exceed corn forage quality under these climatic conditions.

The average 32.8% present in grain sorghums, is lower 34.7, 38.7 and 37.7% observed in the literature (4, 18, 20), respectively, for conventional forage sorghums. In a more recent study (7) made with a grain sorghum variety that was evaluated for three years (2007, 2008 and 2009), a value of 25.7% was found, less than in this study.

In the first three researches, a higher silage DM content (~30.6%) than the one obtained in this study (27.0%) was reported, which implies greater maturity of the plant, which could explain the increase of ADF in those forages. In the fourth study (7), the harvest was made at the same level of DM in plant (30.0%) in the three years of evaluation. In 2007, the grain presented a milky-dough consistency, while in 2008 and 2009 the consistency was milky; this implies that, at the same DM level, plant maturity is different due to the influence of climatic and edaphic factors presents between periods or between soils. This influences the cell walls content; that in this study was 27.9% of ADF in 2007, similar to the one obtained in this study, and 24.6% and 24.3% in 2008 and 2009.

The ADF (26.3%) present in sorghum SM350 bmr silage, is lower than the 28.5 and 33.6% observed in sorghums bmr-18 and bmr-6 (21) and to 36.5% (4). In another study (22) were reported 26.8 and 26.2% for sorghums bmr-12 and bmr-6, values that are similar to the one obtained in this study.

Acid detergent lignin (ADL)

The ADL showed a behavior similar to that of ADF. Thus, the ADL content was equal ($p>0.05$) among grain sorghum silages, with average of 3%; but this average was higher ($p<0.05$) compared with SM350 and corn A7573 silages, that were equal (table 2, page 360). The content of ADL in silage SM350 was 36.4% lower ($p<0.05$) than the average of grain sorghum silages and 13.6% higher ($p>0.05$) than corn A7573 silage.

In grain sorghum silages, ADL coincides with 2.9% observed in the literature in average (7, 21), but it is lower than 5.7, 6.5 and 7.0% reported in other studies (11, 19, 22), respectively. In these last three studies, the highest ADL content can be attributed to maturity stage which sorghums were harvested; for example, in the study (22) the harvest was made in grain full and hard, that is a greater maturity stage to which the sorghums were harvested in this study. This maturity effect, also is observed in the study (7), where the sorghum was harvested in two different stages: milky-dough and milky, with averages of 3.6 and 2.5% ADL, respectively.

In other study (6), report 3.1, 3.5 and 3.8% of ADL for three grain sorghum varieties, being first value more similar to that one observed in this study.

The ADL content in silage sorghum SM350 was 2.2% and was equal ($p>0.05$) to 1.9% observed in corn silage A7573. In this regard (21), they reported 2.3 and 2.5% for sorghums bmr-6, bmr-18, respectively. In other research, reported for the same sorghum of bmr Silo Honey-350 and for Green Giant Sorghum (AgriBio Tech®) 2.5 and 2.1% of ADL, at 24.5 and 25.0% DM level, respectively (8).

In other studies, higher values have been reported (22); however, this higher

ADL concentration is relate to the harvest at the most advanced maturity stage. For example, it has been observed that when the harvest is made in grain milky stage, the ADL is below 3.0% of DM, while in milky-dough it is above this value.

The similar ADL content observed in this study between silage SM350 and corn A7573, make bmr sorghums, a good option to produce good forage quality, especially when are established in dry season of year in the humid tropics. This advantage is attribute to the lower lignin content of these sorghums and their capacity to grow in drought conditions, where the production of corn forage represents a greater risk.

Based on these results, the maturity stage and variety have a marked effect on the fiber and lignin content in the sorghum forage, where structure and relationship of plant components (stem:leaf:panicle) contribute to significant way on forage quality in different genotypes (26). Grain sorghums, due to their own characteristics, have higher fiber content and lower digestibility than conventional forage sorghums and bmr; the latter surpassing even conventional foragers. However, the forage of whole corn plant surpasses in yield and quality any type of sorghum, even under certain critical levels of humidity in the soil, as happened in this study and the Marsalis *et al*. (2009) study.

In situ dry matter disappearance

Parameters degradation of dry matter were affected by forage type ($p<0.05$). Parameters *a*, *b* and *c* were higher in sorghum silage SM350 compared to grain sorghums. Sorghum silage Niquel showed greater degradation of fraction *b* than its homologue DK67 (table 3).

Table 3. Kinetic parameters (%) of *in situ* ruminal disappearance of dry matter of silages.

Tabla 3. Parámetros (%) de la cinética de degradación ruminal *in situ* de la materia seca de los ensilados.

	Silages			
Parameters	**DK67**	**Niquel**	**SM350**	**A7573**
a	32.5 ± 1 ^{c}	30.5 ± 1 ^{d}	34.3 ± 1 ^{b}	35.2 ± 1 ^{a}
b	42.0 ± 5 ^{d}	48.3 ± 5 ^{c}	49.0 ± 3 ^{b}	50.5 ± 3 ^{a}
c (% hour^{-1})	2.4 ± 0.6 ^{c}	2.0 ± 0.4 ^{d}	2.7 ± 0.4 ^{b}	2.8 ± 0.5 ^{a}
Estimated				
PD (72 h)	75.1 ± 1.9^{b}	80.1 ± 1.9^{ab}	83.3 ± 1.9^{ab}	86.0 ± 1.9^{a}
IF	24.9 ± 1.9^{a}	19.9 ± 1.9^{ab}	16.7 ± 1.9^{ab}	14.0 ± 1.9^{b}
ED (k_p= 5 % h^{-1})	46.0 ± 0.5^{b}	44.6 ± 0.5 ^{b}	51.5 ± 0.5 ^{a}	53.5 ± 0.5^{a}
ED (k_p= 2 % h^{-1})	55.3 ± 0.6^{b}	55.1 ± 0.5 ^{b}	62.5 ± 0.6 ^{a}	64.9 ± 0.6^{a}

abcd = Means with different letter in the same row, differ significantly ($p≤0.05$).

a = soluble and rapidly degradable fraction; b = insoluble fraction and slowly degradable; c = degradation rate (% h^{-1}) of fraction b; kp = passage rate through rumen (% h^{-1}); PD = potential degradability (a + b) of substrate at 72 h incubation; IF = indigestible fraction (100 - (a + b)) of substrate; ED = effective degradability with kp at 5 or 2%, for medium and low milk production level (19).

abcd = Medias con diferente letra en el mismo renglón, difieren significativamente ($p≤0,05$).

a = fracción soluble y rápidamente degradable; b = fracción insoluble y lentamente degradable; c = tasa de degradación (% h^{-1}) de la fracción b; kp = tasa de pasaje por el rumen (% h^{-1}); DP = degradabilidad potencial (a + b) del sustrato a 72 h de incubación; FI = fracción indigestible (100 - (a + b)) del sustrato; DE = degradabilidad efectiva con kp a 5 o 2 %, para media y baja producción de leche (19).

On the other hand, corn silage A7573 presented the highest values ($p<0.05$), this result confirms the nutritional quality maintained by this forage species, even under conditions of water stress.

The potential degradability (PD) at 72 h incubation, was higher in the corn silage A7573, but was not different from SM350 and Niquel silages, while DK67 silage showed the lowest value ($p<0.05$). The indigestible fraction (IF) was similar among sorghums and was lower in corn silage A7573, which showed no difference with SM350 and Niquel silages. The effective degradability (ED) at a Kp of 5 or 2%, showed the same tendency among silages; was higher in corn A7573 and sorghum SM350 silages and lower in grain sorghums silage (table 3, page 363).

The results of degradation kinetics observed in this research are consistent with previous studies (9, 30). This similarity in results may be because sorghums were harvested at a similar stage of maturity and, therefore, the chemical composition was similar. For example, in those studies the soluble fraction was 32.4 and 37.8% in grain sorghum silages, respectively. For their part, in the second study (30) reported 45.6% in *b* fraction, similar to obtained with sorghum Niquel. Other studies there are greater differences in results (5, 12).

The differences in results can be explained by the different conditions under experiments were development. Is knowledge that factors such as soil type, cultivar, climate, maturity stage, plant or seed density, etc., significantly influence the chemical composition forages (15). These factors alter, for example, fiber fractions and their relationship with lignin, which in turn influences enzymatic activity carried out by rumen bacterial on cellulose and hemicellulose polysaccharides, resulting in important changes in dry matter degradability and, finally, affects forage intake and animal performance (17, 22).

Although total precipitation (103.5 mm) occurred in the experiment was low, corn cultivar had good acceptable yield and higher forage quality than grain sorghum silages types. Brown midrib sorghums, such as SM350, because low lignin content, are good option in terms of forage quality in water deficit situations, since corn cultivars cannot be established; however, this sorghum types tends to have lower forage yield (15).

Regarding the grain sorghums silages cultivars, such as DK67 and Niquel, for their adaptation to the prevailing climate in humid tropics, can compete in yield with corn silage; however, their high content of cell walls can limit dry matter intake and animal performance.

Conclusions

In the humid tropics, grain sorghums DK67 and Niquel showed high forage yield, but the silage quality was low. Due to their adaptation to the edaphoclimatic conditions of region, these sorghums are a viable alternative to produce high silage yields comparable to those of corn silage.

The sorghum SM350 bmr, planted in December produce a high quality silage during the dry season, even greater than corn silage. Despite having less soil water availability, corn silage showed similar yield and more digestible nutrients per hectare than sorghums.

Under this scenario, research is required to determine under what level of water deficit sorghum can surpass corn yield and nutritive forage value. Because their low forage yield, RB-Huasteco and RB-Norteño sorghums are not recommended as an option to produce good silages in this region of country.

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