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PASTURE AND FORAGE UTILIZATION

Agronomic performance and nutritive value of millet silages

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ABSTRACT. The objective of this study was to assess agronomic characteristics and nutritional values of silages of millet genotypes. Planting was done in randomized blocks, with five replicates per genotype. Green matter yield for genotypes ADR 500 and CMS 01 was higher and similar to each other, with 40.16 and 41.36 t ha ($p > 0.05$). There was no significant difference for dry matter yield, with the mean being 9.93 t ha ($p > 0.05$). The silages were similar ($p > 0.05$) as to pH, Aw and N-NH3/TN, presenting values of 3.92, 0.97 and 7.64%, respectively. There were no significant differences ($p > 0.05$) concerning the bromatological composition of the silages of the different genotypes, with a mean of 30.74% of dry matter, 10.21% for crude protein and 58.69% for neutral detergent fiber ($p > 0.05$). The dry matter digestibility mean stood at 59.90%. Based on the nutritional values and digestibility of the millet silages, the five genotypes are suitable for silage production, with potential for the North of Minas Gerais.

Keywords: digestibility, dry matter yield, silage.

Desempenho agronômico e valor nutritivo das silagens de milheto

RESUMO. Objetivou-se com este trabalho avaliar as características agronômicas e o valor nutricional das silagens de genótipos de milheto. O plantio foi realizado em blocos casualizados, com cinco repetições por genótipo. A produção de matéria verde para os genótipos ADR 500 e CMS 01 foram superiores e semelhantes entre si, com 40,16 e 41,36 t ha ($p > 0,05$). Não houve diferença significativa para a produção de matéria seca, e a média foi de 9,93 t ha ($p > 0,05$). As silagens mostraram-se semelhantes ($p > 0,05$) em relação ao pH, Aw e N-NH3/NT, apresentando valores de 3,92; 0,97 e 7,64%, respectivamente. Não foram encontradas diferenças significativas ($p > 0,05$) em relação à composição bromatológica das silagens dos diferentes genótipos, sendo observados médios de 30,74% de matéria seca; 10,21% para proteína bruta; 58,69% para fibra em detergente neutro e ($p > 0,05$). A média da digestibilidade da matéria seca foi de 59,90%. Com base no valor nutricional e na digestibilidade das silagens de milheto, os cinco genótipos apresentam-se adequados à produção de silagem com potencial para o norte de Minas Gerais

Palavras-chave: digestibilidade, produção de matéria seca, silagem.

Introduction

In tropical conditions, the greatest challenge in ruminant production is the adequacy to shortages of rain and, consequently, of food, since pastures are sources of food for the animals. Alternatives to overcome annual oscillations in the availability and quality of pastures and to make the system more sustainable include using bulks preserved in the form of silage.

Although millets are grown in Brazil since the mid-1960s, new varieties and enhanced hybrids have emerged in recent years, presenting certainly different nutritional values. Characterized by annual forages of high nutritional value, they can be used for grain production, mulch and as forage for grazing and ensilage.

Due to its high resistance to droughts, millets grow in regions with annual precipitation between 200 and 800 mm and annual average temperature of 18 to 30ºC. It is inferred that millet crops, besides rusticity, present great adaptability to semi-arid environments. The grass allows rotation between grain production and animal production, being a form of agriculture/livestock integration. In this type of management, millets are usually sown after the harvest of the summer crop, known as second crop (Amaral, Evangelista, Salvador, & Pinto, 2008). With the growth of livestock production, millets began to be used as bulk in the form of pasture and silage, which consists of a dual-purpose crop, serving for grain production and mainly forage production, given the high quality of the product compared to other forages (Kollet, Diogo, & Leite, 2006).

According to Guimarães Jr. et al. (2008), the chemical composition of millet silages is variable, with the time of cutting of the plant to be ensiled and the assessed cultivar being of great importance. Silages made with plants harvested 100 days after planting showed crude protein contents around 11% and *in vitro* dry matter digestibility of 54%. The silage of millets harvested at dough stage is equal to maize silages as to digestibility. However, it has higher levels of crude protein and dry matter and can be considered of better quality. According to Valadares Filho et al. (2010), maize, regarded as a reference food, has silage with contents of 6.73% of crude protein and 56.6% of dry matter digestibility.

In this way, further studies on agronomic characteristics and nutritional values of millet cultivars are necessary to establish the best genotypes for different regions. Thus, the objective was to assess agronomic characteristics, fermentation and nutrition parameters, as well as the digestibility of the silages of five millet genotypes in the northern region of Minas Gerais.

Material and methods

The experiment was conducted in 2013 at Brazilian Agriculture Research Corporation (EMBRAPA) experimental field, located in the municipality of Janaúba, in the northern region of Minas Gerais. The climate classification, according to Köeppen, is Aw, that is, savannah with dry winter. The soil of the region is classified as Red-Yellow Latosol. Treatments consisted of 5 millet genotypes: ADR 500, CMS 01, CMS 03, BRS 1501 and SAUNA B.

Before planting, the soil was analyzed through the collection of samples from the surface horizon (0 to 20 cm), coinciding approximately with the plowing layer, where the biggest portion of roots develop. The analyses were carried out in the Laboratory of Soils of the Department of Agrarian Sciences at the State University of Montes Claros [*Universidade Estadual de Montes Claros*] - UNIMONTES, Janaúba, Minas Gerais State. Based on soil analysis and crop requirements, correction and fertilization were performed. In the planting fertilization, 300 kg ha of formulation 04-30-10 (N-P-K) were used. Thirty-Five days after planting, a cover fertilization was done using 60 kg ha of N, having urea as source.

The experiment was implemented in a randomized block design, with 5 replicates per genotype, totaling twenty five plots. Each block was formed with 5 treatments. Twenty seeds were sown per linear meter in each plot for the 5 genotypes. Each plot was composed of six rows measuring six meters in length and seventy centimeters of row spacing. At the end of the vegetative cycle, 82 days after planting, agronomic characteristics and cutting were assessed for ensilage.

Assessments were carried out in four rows of each plot of the seedbed (useful area), removing 1 m at the ends of each row and the two side rows of each plot (the borders). Thus, in the two center rows, agronomic characteristics were assessed and, in the two intermediate rows, silage characteristics. The agronomic characteristics assessed were: plant height at the time of cutting; green matter yield, obtained with the weighing of all plants in the useful area of the plot, performed after cutting fifteen centimeters above the soil; dry matter yield, obtained from the green matter yield and dry matter (DM) content of each genotype at the time of cutting.

For the ensiling process, laboratory silos were used, made of PVC tubes measuring 100 mm in diameter and 500 mm in length, with the millet being chopped in a stationary chopper and pressed with a wooden socket, adopting an average density of 600 kg M_{-3}. The silos were sealed with PVC caps provided with Bunsen-type valves and sealed with adhesive tape. There were 5 replicates per treatment and three replicates per plot, with the making of 75 silos in total that, after 56 days of ensilage, were opened to assess the quality and nutritional value of the silages.

Laboratory analyses were performed at the Department of Agrarian Sciences' Food Analysis Laboratory. When the silos were opened, the ends were removed and the remaining material was homogenized and sampled. With the aid of a hydraulic press, approximately 200 mL of silage juice were extracted to determine pH values, using a specific potentiometer (pH meter-3 MP, Tecnal), and ammoniacal nitrogen content, in accordance with Bolsen, Lin and Brent (1992). The water activity (AW) of the silages was assessed using the Aqua Lab 4TE DUO equipment.

Part of the silage was distributed into duly identified paper bags, then weighed and put inside a forced ventilation oven at 55°C, where they remained for 72 hours, being weighed again to obtain the pre-dried matter. The pre-dried samples were milled in a stationary mil, with a 1-mm mesh sieve, and then stored in capped and identified plastic containers. The chemical analysis of the millet silages consisted of determining dry matter (DM) contents in greenhouse at 105ºC, crude protein (CP) contents by the Kjeldahl method, ethereal extract (EE) by the goldfish method, neutral detergent fiber (NDF), in accordance with methodology described in the INCT-CA manual (Detmann et al., 2012), and total digestible nutrients (TDN), in accordance with National Research Council [NRC] equations (2001). Total carbohydrates (TC) were determined following the equations below: TC (%) = 100 – (CP% +% EE% +Ash%). In its turn, *in vitro* dry matter digestibility (IVDMD) was determined with the samples pre-dried at 55°C and in accordance with methodology modified by Holden (1999), with the change of the bag material used (TNT; 7.5 x 7.5 cm), made of nonwoven fabric (100 g m^{-2}), according to Casali et al. (2008). IVDMD (%) was calculated through the following equation = (100 x (sample weight - (residue weight (sample after incubation) - weight of the white bag residue (after incubation)))/ sample weight. The digestible dry matter yield (DDMY) for each genotype was calculated with the following equation: DDMY = (DM% 105 ºC x IVDMD%).

Data obtained in the field were subjected to statistical analysis using the Variance Analysis System (SISVAR) and, for comparison of means, the Scott - Knott test at a 5% level of significance was adopted, as shown in the following statistical model:

Yik: μ + Gi + Bk + eik

where:

Yik = value observed for genotype i, submitted to block k;

μ = overall mean;

Gi = genotype i effect, with i = 1, 2, 3, 4 and 5;

Bk = block k effect, with k = 1, 2, 3, 4 and 5;

Eik = experimental error associated with observed values (Yik).

Results and discussion

Regarding agronomic assessment, there was significant difference ($p < 0.05$) between genotypes as to the following characteristics: plant height in meters and green matter yield in tons per hectare. There was no significant difference ($p > 0.05$) for dry matter yield in tons per hectare (Table 1).

Table 1. Average number of plants per hectare (NP ha), mean values of height (m), in meters, green matter yield (GMY, t ha) and dry matter yield (DMY, t ha) of five millet genotypes.

Parameters	ADR 500	BRS 1501	CMS 01	CMS 03	SAUNA B	Mean	CV %
Height (m)	1.66 b	1.81 b	2.15 a	1.76 b	1.49 b	1.77	15.25
GMY (t ha)	40.16a	35.71b	41.36a	36.39b	32.68b	37.31	9.11
DMY (t ha)	10.47a	9.29a	10.64a	10.20a	9.07a	9.93	15.60

Means followed by identical lowercase letters, on the same line, mean statistical similarity ($p > 0.05$) by the Scott-Knott Test. CV = Coefficient of variation.

The genotypes were different ($p < 0.05$) as to plant height at the time of cutting, with CMS 01 being the tallest, with 2.15 meters. The other genotypes were similar to each other (Table 1). The taller the plant, the greater the green matter yield, which is a desirable characteristic for the genotype; however, the taller the plant, the greater the possibility of lodging, an undesirable factor. The importance of knowing the number of plants per hectare and the plant height of the different genotypes is due to the positive correlation that is expected between them and green matter yield. Therefore, the genotype with the largest number of plants and/or that reaches a taller height can show a higher green matter yield.

There was significant difference between genotypes ($p < 0.05$) for GMY, with ADR 500 and CMS 01 presenting the highest yields, not differing from each other. Genotypes BRS 1501, CMS 03 and SAUNA B were similar, with lower means than the others (Table 1). Comparing genotypes ADR 500 and CMS 01, it was observed that, although ADR 500 was superior to CMS 01 as to number of plants per hectare, it had shorter plant height, thus causing the similar matter green yield. That is, one characteristic made up for the other; the genotype with smaller number of plants developed and reached a taller plant height. Pedrico, Santos, Machado, Negreiros Neto and Gomes (2010), researching millets sown in different spacings, reported green matter yield varying from 18.32 t ha, in the largest spacing (0.65 m), to 28.63 t ha, in the smallest spacing (0.25 m). Compared to the present study, where row spacing was 0.70 m, GMY t ha^{-1} was lower than those found here.

About DMY (t ha), there was no significant difference ($p > 0.05$) among the millet genotypes, with an overall mean of 9.93 t ha (Table 1). Climate differences act directly on the yielding of forages. Despite the superiority of dry matter yielding in regions with higher rainfall, the millets showed good yielding potential in semi-arid conditions. Although DMY relates to GMY, it can be observed that the genotypes were different in relation to GMY, but similar as to DMY (Table 1). This is due to the dry matter content of each genotype at the time of cutting. It is also possible to infer that the millet genotypes may have presented different morphogenesis, of which the genotype with higher GMY may, for instance, have larger stem diameter and/or the genotype with lower GMY, in turn, more grains, thus explaining the difference in GMY and the similarity in DMY. The millet genotypes showed good DMY, though planted late, at the end of the rainy season, revealing good forage potential for the northern region of Minas Gerais.

All silages had pleasant odor, brown coloration, firm texture and no moldy parts. The silages of the five genotypes were similar ($p > 0.05$) as to pH, Water Activity (Aw) and ammoniacal nitrogen/total nitrogen ratio ($N\text{-}NH_3/TN$; Table 2). The analyzed parameters are important indicators of the quality of the silage, which fall within the indicated values for silages of great quality.

Table 2. Mean values of pH, Water Activity (Aw) and ammoniacal nitrogen/total nitrogen ratio ($N\text{-}NH_3/TN$) of silages of five millet genotypes.

Parameters	ADR 500	BRS 1501	CMS 01	CMS 03	SAUNA B	Mean	CV%
pH	3.9a	3.9 a	3.8 a	4.0 a	3.9 a	3.92	5.96
Aw	0.97 a	0.97 a	0.97 a	0.97 a	0.97 a	0.97	0.25
$N\text{-}NH_3/TN$ (%)	7.59 a	8.57 a	7.15 a	7.33 a	7.58 a	7.64	21.59

Means followed by identical lowercase letters, on the same line, mean statistical similarity ($p > 0.05$) by the Scott-Knott Test. CV = Coefficient of variation.

The mean pH value of the millet silages was 3.92 (Table 2) and, according to Tomich, Rodrigues, Gonçalves, Tomich and Borges (2004), pH values between 3.8 and 4.2 are considered adequate for well-preserved silages because in this range there is a restriction of proteolytic enzymes in the plant and of enterobacteria and *Clostridium* bacteria, which are responsible for producing butyric acid and deteriorating the silage.

According to Jobim, Nussio, Reis and Schmidt (2007), Aw in ensiled foods is of great importance for the quality of fermentation. Studies conducted in Brazil, with tropical species, show relatively high values for Aw in grass silages, with Aw indicating level of water in its free form in materials and being expressed on a scale from 0 to 1.0 Aw. The value 0 (zero) is considered for water-free materials and 1.0 for water in its liquid form. In this research, it can be observed that the mean Aw was 0.97 (Table 2); however, as previously mentioned, the pH range of the silages was adequate to the restriction of clostridia, preventing undesired fermentation.

A study published by Araújo et al. (2007) found that an increase in the DM content of grass silages evidences reductions in the microbial population, especially clostridia. In silages of wilted materials, little microbial activity is evident due to the low concentration of organic acids and consequent higher pH (Jobim et al., 2007).

As for the $N\text{-}N\text{-}NH_3/TN$ parameter, the overall mean of the genotypes was 7.64% (Table 2). The $N\text{-}NH_3/TN$ ratio in this study was lower than 11%, which is the maximum $N\text{-}NH_3/TN$ content allowed for good quality silages (Ohshima & McDonald, 1978). The $N\text{-}NH_3/TN$ ratio, expressed as total nitrogen percentage, indicates the amount of protein degraded during the fermentation phase. Therefore, this parameter is one of the most important in determining the quality of the fermentation process of the ensiled mass. Thus, poorly preserved silages present ammonia contents higher than 10%, with ammonia being derived from amino acid catabolism.

The DM contents of silages of the 5 genotypes did not differ from each other ($p>0.05$), and the average content stood at 30.74% (Table 3).

Table 3. Mean values of dry matter (DM), crude protein (CP), ethereal extract (EE), neutral detergent fiber (NDF) and total carbohydrates (TC) of silages of five millet genotypes.

Parameters	ADR 500	BRS1501	CMS01	CMS03	SAUNA B	Mean	CV%
DM (%)	30.08 a	31.55 a	29.33 a	32.84 a	29.90 a	30.74	7.0
CP (%)	10.17 a	10.73 a	10.54 a	9.82 a	9.78 a	10.21	11.73
EE (%)	2.44 a	2.29 a	2.56 a	2.16 a	2.30 a	2.35	19.51
NDF (%)	57.59 a	58.68 a	55.75 a	61.42 a	60.01 a	58.69	5.81
TC (%)	76.28 a	76.67 a	75.22 a	76.10 a	78.86 a	77.03	2.75

Means followed by identical lowercase letters, on the same line, mean statistical similarity ($p > 0.05$) by the Scott-Knott Test. CV = Coefficient of variation.

Variation in the dry matter content of the silage depends, in addition to factors inherent to the genotype, on the age of the plant at the time of cutting. Younger plants, at development stage, have higher water contents in their constitution and, consequently, lower dry matter concentration. In the present study, cutting was performed after the plants had completed their physiological maturation stage, thus seeking maximum dry matter yield related to the period of better nutritional quality and to good dry matter content for an adequate fermentation profile.

When it comes to crude protein (CP) levels, there was no significant difference between genotypes ($p > 0.05$), with the mean content being 10.21% (Table 3). The CP values obtained in this study were similar to those reported by Amaral et al. (2008), between 7.28 and 9.40%. In this research, all silages of the millet genotypes showed enough CP to ensure good ruminal fermentation.

The ethereal extract (EE) contents of silages of the 5 genotypes did not differ ($p > 0.05$), with the mean content being 2.35% (Table 3). Avelino et al. (2011), studying the bromatological composition of silages of hybrid sorghum forage, commonly used in the northern region of Minas Gerais, observed for AG-2005 (dual-purpose) and Volumax (forage), EE levels ranging from 1.61 and 2.05%. These results are inferior to those of this research, stating the possible replacement of traditional forage food by one that is more adaptable to regional conditions. There are few studies that report ethereal extract levels of millets, although fat is the most energetic fraction of food. The higher the fat content of a food, the higher the TDN value.

About fibrous parameters – Neutral Detergent Fiber (NDF) and Total Carbohydrates (TC) –, no significant difference ($p > 0.05$) was found among genotypes (Table 3).

The mean content for Neutral Detergent Fiber (NDF) was 58.69 (Table 3). NDF content is an indicative of the amount of forage fiber, with NDF being related to the amount of fiber in the bulk (Santos et al., 2010). For Van Soest and Manson (1991), NDF values above 55 to 60% correlate negatively with the consumption of dry mass by the animal. It can be observed that the millet silages studied herein present NDF values within the range recommended not to limit dry matter consumption. Regarding TC contents, the mean content found was 77.03% (Table 3). The millet genotypes, as it can be observed in this study, have in their composition lower TC levels; in contrast, millets generally have greater rusticity, which allows them to be cultivated in regions where corn does not grow well.

For values referring to estimated Total Digestible Nutrients (TDNe), *in vitro* dry matter digestibility (IVDMD) and digestible dry matter yield (DDMY), no significant differences ($p > 0.05$) were observed between silages of the five millet genotypes. The mean valuesfound were 57.96% of TDNe, 59.90% of IVDMD and 4.15% of DDMY (Table 4).

Table 4. Values referring to estimated total digestible nutrient (TDNe), *in vitro* dry matter digestibility (IVDMD) and digestible dry matter yield (DDMY) of silages of the five millet genotypes.

Parameters	ADR 500	BRS1501	CMS01	CMS03	SAUNA B	Mean	CV %
TDNe (%)	57.08 a	56.61 a	57.73 a	59.51 a	58.88 a	57.96	4.45
IVDMD (%)	58.27 a	61.04 a	59.17 a	61.12 a	59.90 a	59.90	6.93
DDMY (t ha)	4.29 a	3.95 a	4.41 a	4.37 a	3.73 a	4.15	16.1

Means followed by identical lowercase letters, on the same line, mean statistical similarity ($p > 0.05$) by the Scott-Knott Test. CV = Coefficient of variation.

Costa et al. (2011), studying millet pastures, observed lower TDN contents, reporting a mean of 54.8% of TDN. These values are close to the TDN found in this research.

From the IVDMD, it is possible to know the digestible fraction of each nutritional component as well as to estimate DDMY in tons per hectare. Millet cultivation seeks to minimize the conflict caused by long droughts in semi-arid regions. Thus, a crop that is resistant to climate adversities and produces 4.15 t ha^{-1} of digestible dry matter becomes a viable alternative to feed ruminants.

The answers obtained from the assessment of agronomic characteristics of millet genotypes, as well as of the quality and nutritional values of the silages confirm the possibility of diffusion of these varieties for silage production in semi-arid regions, which lack forage options and have remarkable regional peculiarities.

Conclusion

The millet genotypes – ADR 500, BRS 1501, CMS 01, CMS 03 and SAUNA B – showed adequate agronomic characteristics and nutritional values for silage production, with satisfactory fermentation pattern and good digestibility.

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