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Short Communication

Yield and quality of silage of maize hybrids

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ABSTRACT - The objective of this research was to identify the potential of maize hybrids for the production of silage. Hybrids 1671B, 2B433, 20A78, SHS4070, BX1280 and DKB390 were tested in a randomized block design with three replications. The hybrids yields were evaluated (average plant height, height of ear insertion, number of broken and lodged plants/ha, leaf:stem and ear:plant ratio and production of of DM, CP and TDN/ha). There was no difference between hybrids for the variables studied, except for the height of ear insertion. With respect to chemical characteristics, N-NH3/NT organic acids, and pH, there was also no difference between cultivars and hybrid silages are rated as of very good quality.

Key Words: fermentation profile, nutritional value, *Zea mays*

Introduction

With the development of the Brazilian agriculture, more efficient production systems are more and more demanded, as imperative to increase competitiveness and ensure sustainability. In this aspect, the need for investments and the use of animals of higher genetic potential, which require a well balanced diet of high nutritional value, increases. In this context, the production of forages in sufficient quantity and quality throughout the year becomes a necessity in all production systems that aim at higher productivity.

Thus, ensilage has been used as an alternative in fodder preservation with view to greater productivity and animal performance, and the maize silage is the most common one used in Brazil.

This large use of maize for silage making is mainly because of its chemical composition, which meets the requirements to making good silage, has high productivity, low buffering power and adequate levels of soluble carbohydrates (Nussio et al., 2001); attributes that allow the conservation of this roughage with quality.

However, there have been attempts to identify hybrid with better production potential and nutritional quality for silage, with good rate between stems, leaves and grains, and high digestibility, since there is a high correlation between the nutritional value of a culture and its silage (Pereira Filho & Cruz, 2001). The higher proportion of grain in the material to be ensiled is desirable, for it contributes to the increase of the dry matter content of the silage, as far as there is no high proportion of straw and corn cob, which can reduce the effect of the ear in its quality (Almeida Filho et al., 1990). It is also necessary to consider other fractions of the plant, as the nutritional quality of the stem has strong correlations with the nutritional quality of the whole plant (Nussio et al., 2001).

The preservation of fodder silage is an anaerobic fermentative process, which converts soluble carbohydrates of the plant into organic acids by microbial activity. The silage quality depends on the efficiency of this process and the conditions that determine it, such as humidity, temperature, presence of oxygen, concentration of soluble carbohydrate and productive characteristics of the plant silage (Neumann, 2001).

Thus, the objective of this study was to evaluate production characteristics of six maize hybrids and also their fermentation quality and chemical composition of silages made of them.

Material and Methods

The experiment was conducted at the Experimental Farm Risoleta Neves (FERN) located in São João Del Rey,

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under a use-agreement between UFSJ/EPAMIG, on a soil classified as Red Latosol, in a non-irrigated area.

A soil analysis showed the following characteristics: pH - 5.6; P - 1.2 mg/dm^3; Al^{+++} - 0.3 mg/dm^3; K - 37.1 cmol/dm^3; Ca^{++} - 0.2 cmol/dm^3; H^+ + Al^{+++} - 1.5 mg/dm^3; Mg^{2+} - 0.2 cmol/dm^3 and organic matter - 0.96 mg/dm$^{3.}$

Six hybrids (treatments) of maize (1671B, 2B433, 20 A 78, SHS4070, BX1280 and DKB390) were evaluated in randomized block with three repetitions, comprising 18 plots, consisting of four rows of five meters, and the two central rows as useful area. The spacing used was 80 cm between rows. Maize fertilization was carried out accordingly to the chemical analysis of the soil, using 450 kg/ha NPK (8-28-16). There was also top dressing fertilization, 400 kg/ha of (NPK) 20-00-20 were applied 30 days after emergence.

To evaluate the components related to the productivity of each maize hybrid, the following characteristics were determined: average plant height, taken in centimeters from the ground to the flag leaf insertion; height of ear insertion, in cm; number of lodged and broken plants per hectare; leaf:stem ratio ear-plant ratio, and production of dry matter by hectare (DMP/ha). To determine the ratio between ear and plant stem, total weight of green mass (whole plant) by plot was determined initially. Subsequently, ears, stems and leaves of the plot were weighed and then their percentages in green mass were determined.

The yields of total digestible nutrients (TDN/ ha) and crude protein per area (CP, t/ha^{-1}) were obtained by the product of the production of dry matter per area (DMP, t/ha^{-1}) and (CP, t/ha^{-1}) and the content of TDN and CP in the silage DM, in percentage.

About 110 days after planting, when the grains presented a flouring aspect, manual cut, disintegration and ensilage of maize hybrid were performed. For the making of the mini-silos, 12 kg fresh material-capacity plastic buckets, with storage density of 500 kg/m^3 were used, in which Bunsen valves were adjusted in the covers to allow gas flow. After filling, the buckets were tightly sealed with adhesive tapes preventing air exchange with the environment.

At the end of the process of ensiling (microbiological stabilization), approximately 45 days after closing, approximately 400 grams were removed from samples of each homogeneous bucket, and taken to dry in air circulation warming chamber at 55-60 °C for 72 hours. Subsequently, these samples were weighed and processed in knife mills (1 mm) and packed in plastic bags for analysis of dry matter content (DM), crude protein (CP), acid detergent fiber (ADF), extract ether (EE), lignin (LIG) and mineral matter (MM) according to Silva & Queiroz (2002). The NDF evaluations followed the protocols suggested by Mertens (2002). Chemical analyses were carried out in the Animal Nutrition Laboratory of the Department of Animal Science of Universidade Federal dos Vales do Jequitinhonha e Mucuri -UFVJM.

A fraction of each silage sample repetition was pressed into hydraulics press for juice extraction and then the pH was determined using a digital potentiometer (Digimed). These procedures were carried out within the FERN in São João Del Rey.

The ammoniacal nitrogen /total nitrogen ratio ($N\text{-}NH_3$/NT) and butyric acid content by gas chromatography were determined in accordance with the rules of the AOAC (1995), and lactic acid, by high performance liquid chromatography (HPLC) using Cation exchange column (Polyspher OA HY 51272; Merck, Amsterdam), so that the mobile phase consisted of H_2SO_4 (0.004 mol/L) at a rate of 0.6 mL/minute at 40 °C.

The total digestible nutrients (TDN) were estimated according with the equation adopted by the NRC (2001):

TDN = [DCP + (2.25 × DFA) + DNDFap + DNFC] - 7,
in which: DCP = EXP [-1.2 × (ADIP/CP)];
TDN = total digestible nutrients; DCP = digestible crude protein; DFA = digestible fatty acids; DNDFap = digestible neutral detergent fiber corrected for ash and protein; DNFC = digestible non-fibrous carbohydrates; ADIP = acid detergent insoluble protein.

DFA = EE = Soluble matter in the treatment with petroleum ether, if EE <1; FA = 0;
DNDFap = [0.75 × (NDFap– LIG)] × [1- (LIG/NDFap) 0.667],
in which: NDFap = NDF corrected for ash and proteins;
DNFC = 0.98 × {100 – [(NDF – NDIP) + CP + EE + ASH]} × PAF,
PAF (processing adjustment factor) = 1; NDF = neutral detergent fiber; NDIP = neutral detergent insoluble protein.

The experimental data or measured variables were subjected to analysis of variance and when significant at (P>0.05), compared with the means through Student-Newman-Keuls (SNK) test.

Results and Discussion

The dry matter content of the plant contributes to the conservation of silage by inhibiting the growth of undesirable organisms. The hybrids silage presented an average content of 30.70% without difference between them (Table 1). These values are within the range indicated by Tosi (1973) as ideal to ensure adequate fermentation of silage.

For the variable plant height, there was no difference between the hybrids; the average value found, 216

Table 1 - Sward characteristics of the productive hybrids evaluated

	Hybrids							
Parameters	1671B	2B433	20 A 78	SHS4070	BX1280	DKB390	Mean	% CV
Dry matter, %	29.2	33.a	34.8	28.8	29.0	29.0	30.7	9.78
Plant height, cm	213	212	218	232	217	206	216	302.15
Ear height, cm	125ab	A08B	A10b	1 to 55	130ab	118ab	124	12.52
LP (plants/ha)	0	60.6	33.0	59.4	43.7	9.5	34.4	175.20
BP (plants/ha)	7.7	16.1	25.6	8.5	0	19.0	12.8	192.16
Leaf:stem ratio (g/kg)	330.5	366.1	298.8	260.3	256.0	334.1	307.6	19.79
Plant:ear ratio (g/kg)	351.5	388.6	410.0	305.3	320.3	351.2	354.5	12.00

Means, in rows, followed by lowercase letters differ (P<0.05) by the SNK test.
LP - lodged plants; BP - broken plants.

centimeters, is close to those found by Paziani et al. (2009), who evaluated a database of different maize cultivars in the state of Sao Paulo and found an average height for maize plants of 223 centimeters.

Hybrids SHS4070, 1671B, and BX1280, DKB390 did not differ between themselves regarding the height of ear insertion; however, SHS4070 was superior to 2B433 and to 20A78, which also did not differ from each other compared with that variable. However, the hybrid with the highest plant height (SHS4070) also showed higher height of ear insertion, although it was not significant.

Pinto et al. (2010), leading a study on evaluation of maize for silages, in which 12 cultivars were tested, found variations in plant height between 1.82 and 2.47 m, positively correlating with dry matter production ranging between 17.10 and 18.10 t/ha. Rose et al. (2004), evaluating the agronomic performance of maize plants and the silage nutritional value, found height of 1.84 m and dry matter yield of 12.48 t/ha for hybrid AG-5011.

Also no differences were observed for the variables broken and lodged plants. The lodging resistance and breakdown are important characteristics in choosing the hybrid to be ensiled. The lodging in maize causes severe damage to the yield, quality and the mass of the grains, and difficulty to harvest. Every year losses of 5 to 20% of the world production of maize are estimated due to lodging (Moraes & Brito, 2011).

There was no difference (P>0.05) for the leaf:stem and ear:plant ratios between the hybrids. According with Almeida Filho et al. (1990), a larger proportion of the ears in the silage against the whole plant is desirable, because it contributes to better nutritional quality of silage.

The dry mass yield is one of the first parameters to be assessed, since it is related to the productivity and is used for the sizing of silos. There was no difference between the hybrids tested, with average dry matter production of 13.22 t by hectare (Table 2). These values were lower than those found by Paziani et al. (2009), which ranged from 14 to 25 t. Melo et al. (1999) evaluated some maize cultivars and found yields ranging from12.49 to 29.59 t dry matter/ha.

The variables amounts of TDN and CP produced by area (TDN/ha and (CP/ha) were obtained by the product of dry matter production (DMP/ha) and TDN content and CP in the silage dry matter in percentage. No differences were observed for the production of TDN and CP per hectare, and the values obtained showed satisfactory results for production. Pereira et al. (2006), in a study related to the economic feasibility of tropical forages conservation, show TDN and CP values of maize silage of 8.0 and 0.90 t/hectare/year, respectively. These authors also add that among the conserved forage options, the one which has the lowest production cost by TDN/area is the maize silage.

Knowledge of the dry matter content in the silage is important because based on it, the diet is calculated, since the feed consumption by animals is established in kg/dry matter/animal/day (Table 3).

No differences were observed for variable CP on the hybrid silage. The average value for CP was 5.87%, close to the findings of Oliveira et al. (2010) who found an average of 6.1% protein in the silages assessed. These values are

Table 2 - Productivity of silages from corn hybrids

	Hybrids							
Variables	1671B	2B433	20 A 78	SHS4070	BX1280	DKB390	Mean	% CV
DMP	12.88	11.36	12.83	14.67	14.89	12.71	13.22	23.31
CPP	0.74	0.58	0.79	0.90	0.92	0.70	0.77	27.92
TDNP	8.96	8.55	9.57	10.24	10.41	9.19	9.49	23.24

DMP, CPP and TDNP - production of dry matter, crude protein and total digestible nutrients, respectively, in tons per hectare; CV - coefficient of variation.

Table 3 - Chemical composition of silages from corn hybrids

Variables	Hybrids							
	1671B	2B433	20 A 78	SHS4070	BX1280	DKB390	Mean	% CV
DM (%)	28.85	32.70	34.39	28.48	28.69	28.61	30.29	10.32
CP (g/kg)	55.9	59.0	58.2	57.6	61.6	59.7	58.7	8.55
MM (g/kg)	43.0	32.0	33.9	32.4	43.0	36.5	36.8	19.08
EE (g/kg)	42.9	45.6	38.8	35.5	41.1	41.5	40.9	19.91
TDN (g/kg)	648.9	701.8	697.6	643.8	640.1	665.7	666.3	5.70
ADF (g/kg)	294.6	228.0	223.0	280.0	290.5	253.6	261.6	10.82
NDF (g/kg)	475.1	415.0	400.5	488.6	486.3	449.3	452.5	8.47
Lignin (g/kg)	46.3	34.6	31.2	44.0	44.0	34.9	39.2	21.48

DM - dry matter; CP - crude protein; MM - mineral matter; EE - ethereal extract; ADF and NDF - acid and neutral detergent fiber, respectively; TDN - total digestible nutrients.

lower than those found by Pinto et al. (2010), who evaluated twelve cultivars of corn intended for silage production and found CP concentration between 7.1 and 8.8%.

Also the mineral matter and the ethereal extract contents did not differ between the hybrids studied (P>0.05) and showed, respectively, the following average values: 3.68 and 4.09%, based on DM. Pereira et al. (2007) evaluated the nutritional quality of maize silage and found no difference for the variables mineral matter and ethereal extract. Pinto et al. (2010) found for ether extract, 4.80%, which is close to the value found in this study.

The TDN is indicative of the energy content of feeds and its determination in the silage is essential for balancing and optimization of diets (Capelle et al., 2001). In the silages assessed, the mean level of TDN was 66.63%, lower than those reported by Rose et al. (2004), who observed mean value 69.12%. Among the hybrids tested, there was no difference (P>0.05) between the ADF, composed of cellulose and lignin (fraction non-degradable). This variable is directly related to the silage digestibility, so the lower the ADF content, the greater the digestibility. The ADF concentrations of the silages ranged from 223.0 to 294.6%, similar values to those found by Rose et al. (2004), which were 26.92 to 28.92%. There was no difference for lignin, and their values were the same lower ones reported by Oliveira et al. (2010) and Rose et al. (2004), respectively, 5.9 and 5.49%.

The NDF content of silages ranged from 40.05 to 48.86%, without difference between the hybrids. These values are lower than those found by Pinto et al. (2010), which ranged from 49.1 to 56.2%. Gomes et al. (2004) evaluated the characteristics related to maize silage productivity and observed that the correlations of NDF and degradation were negative in most cases. Thus, the hybrid that showed high degradability usually had low percentage of NDF, as such characteristic represents a portion of the indigestible forage, which makes results of NDF found in this study important.

One of the parameters used to assess the quality fermentation of the silage is the pH. The pH values found for the hybrid silage evaluated were similar (Table 4), and are all within the limits for classification of good quality silage.

The mean value observed in silages of different maize hybrids was 3.75, considered excellent, since it is in the range between 3.7 to 4.2, recommended by McDonald (1981) to ensure good preservation of silage. According to Neumann (2001), the acidity is considered an important factor for the preservation of the silage; it acts by inhibiting or controlling the growth of undesirable microorganisms such as bacteria of the *Clostridium* genus.

The concentration of N-NH_3/NT is an indicative of protein degradation during the ensiling process. Accordig to Ferreira (2001), good quality silage has N-NH_3 lower than 10%. All silages studied presented indices quite below this percentage, which indicates that there was reduced degradation of the protein.

Various organic acids are produced during the silage fermentation, but for the assessment of the quality of fermentation, the most commonly used ones are lactic and butyric acids. In this study, there were no differences (P>0.05) between the profile of these acids of silages from hybrids. According to Oliveira (2001), maize silage are

Table 4 - pH and organic acid values in percentage of dry matter dry of corn hybrid silages

Parameters	1671B	2B433	20 A 78	SHS4070	BX1280	DKB390	% CV
pH	3.83	3.83	3.70	3.73	3.8	3.66	3.13
N-NH_3 (%)	3.19	3.02	2.68	2.64	3.32	2.94	20.50
Lactic acid (%)	6.72	6.27	4.80	5.96	5.71	7.21	29.30
Acetic acid (%)	1.94	2.07	1.93	2.02	1.11	1.96	46.21
Butyric acid (%)	0.036	0.030	0.026	0.044	0.035	0.030	32.5

CV - coefficient of variation.

considered of good quality when they have values between 6 and 8% of lactic acid in the DM, which is primarily responsible for lowering the pH of the silage. According to McDonald (1981), a minimum concentration of 3% is indicative of good quality silage. Thus, one can consider that the silage hybrids are evaluated within values considered ideal, indicating that there was adequate lactic acid fermentation.

Butyric acid, on the other hand, should always be in small quantities, because its presence reflects the extent of the activity of bacteria of the *Clostridium* genus. The content of this acid can be considered a leading indicator of negative quality of the fermentation process (Tomich et al., 2003). Ferreira (2001) recommends for maize and sorghum silages, concentration below 0.1% of DM. Ranjit & Kung Jr. (2000) worked with maize silage and found that butyric acid values ranged from 0.05 to 0.07% of DM. Possenti et al. (2005) found an average of 0.01%, and Rodrigues et al. (2002), 0.07 to 0.20%, with average of 0.14% of this acid in the DM of maize silage. The butyric acid levels of silages are evaluated within the minimum recommended by the various authors cited above, indicating no butyric fermentation that could compromise the quality of the silage.

The mean concentration of acetic acid in the silage of maize hybrids evaluated was 1.83% and is below the threshold (≤2.5%) considered by Tomich et al. (2003) to ensure fermentation quality after opening of the silo.

Conclusions

The hybrids evaluated presented similar fermentative, nutritional and production characteristics and are recommended for silage composition.

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