

# ANNALS OF ANIMAL SCIENCE

ISSN: 2300-8733, <http://www.degruyter.com/view/j/aoas>

## ACCEPTED AUTHOR VERSION OF THE MANUSCRIPT:

### **In vitro degradability, gas production, and energy value of different hybrids of sorghum after storage in mini-silos**

**DOI: 10.1515/aoas-2015-0082**

Mirko Cattani<sup>1\*</sup>, Alberto Sartori<sup>2</sup>, Valerio Bondesan<sup>2</sup>, Lucia Bailoni<sup>1</sup>

<sup>1</sup>Department of Comparative Biomedicine and Food Science, University of Padova, Viale dell'Università, 16, 35020 Legnaro (Padova), Italy

<sup>2</sup>Veneto Agricoltura Agency, Viale dell'Università, 14, 35020 Legnaro (Padova), Italy

◆Corresponding author: [mirko.cattani@unipd.it](mailto:mirko.cattani@unipd.it)

Received date: 30 July 2015

Accepted date: 24 November 2015

**To cite this article:** (2015). Cattani M., Sartori A., Bondesan V., Bailoni L. (2015). In vitro degradability, gas production, and energy value of different hybrids of sorghum after storage in mini-silos, *Annals of Animal Science*, DOI: 10.1515/aoas-2015-0082

**This is unedited PDF of peer-reviewed and accepted manuscript. Copyediting, typesetting, and review of the manuscript may affect the content, so this provisional version can differ from the final version.**

**IN VITRO DEGRADABILITY, GAS PRODUCTION, AND ENERGY VALUE OF  
DIFFERENT HYBRIDS OF SORGHUM AFTER STORAGE IN MINI-SILOS**

Mirko Cattani<sup>1</sup>, Alberto Sartori<sup>2</sup>, Valerio Bondesan<sup>2</sup>, Lucia Bailoni<sup>1</sup>

<sup>1</sup>Department of Comparative Biomedicine and Food Science, University of Padova, Viale  
dell'Università, 16, 35020 Legnaro (Padova), Italy

<sup>2</sup>Veneto Agricoltura Agency, Viale dell'Università, 14, 35020 Legnaro (Padova), Italy

Corresponding author: [mirko.cattani@unipd.it](mailto:mirko.cattani@unipd.it)

Abbreviated title: Nutritional value of sorghum silages

Work financed from Veneto Agricoltura Agency

Project title “Alternative crops rotation to contain diffusion of *Diabrotica virgifera virgifera*  
LeConte”

1 **Abstract**

2 This experiment compared silages obtained from 3 hybrids of sorghum grown on 2 farms of the Po  
3 Valley (one irrigated and one not), in terms of *in vitro* degradability, gas production (GP), and  
4 energy value. Hybrids (forage, sweet or grain genotypes) were sown in experimental plots (3  
5 plots×3 hybrids), harvested at late-milk stage of maturity, and ensiled into mini-silos (3 silos×3  
6 hybrids) for 60 d. After ensiling, silages were analyzed for composition and fermentation profile.  
7 Two incubations (at 48 h) were carried out to measure NDF degradability (NDFd), GP, and the  
8 metabolizable energy (ME) content of silages. Data of silage composition were submitted to  
9 ANOVA, considering farm (F), hybrid (H), and F × H interaction as variation sources. Incubation  
10 (run) was also considered as a fixed effect in the statistical model for the parameters obtained by *in*  
11 *vitro* incubation (NDFd, GP, and energy content). On the irrigated farm (Farm 2), the DM contents  
12 of silages were higher than those of the non-irrigated one (P<0.001) and the fermentation profile  
13 was more favorable. Values of GP at 24 and 48 h and ME content were higher (P<0.05) for silages  
14 of Farm 2 in comparison with Farm 1. Within hybrids, the grain sorghum revealed the greatest DM  
15 content whereas the forage sorghum, as expected, was the richest in fibrous fraction content,  
16 followed by the sweet and grain genotypes (P<0.001). Consequently, values of GP were  
17 significantly (P<0.01) influenced by hybrid (167, 200, 215 ml/g DM and 229, 257, 267 ml/g DM  
18 for forage, sweet and grain genotypes after 24 and 48 h of incubation, resp.). The F × H interaction  
19 was significant for all considered parameters excluding DM, lignin, ash, pH, and *in vitro*  
20 parameters. On the two farms, in general, forage and grain genotypes were largely different,  
21 whereas the sweet sorghum was quite similar to the forage in one case or grain in the other. Results  
22 of this experiment highlight the large variability of the nutritional values of sorghum hybrids grown  
23 in different conditions.

24

25 **Keywords:** Sorghum hybrids; Sorghum silage; *In vitro* degradability; *In vitro* gas production

26

## 27 **Introduction**

28 Silages obtained from sorghums belonging to conventional forage and grain genotypes were found  
29 to be valid feed sources for dairy cows (Dann et al., 2008; Colombini et al., 2012). In the last years,  
30 the potential of sorghum silage as ruminant feed has been evaluated also in Europe. Results would  
31 suggest that the inclusion of such feed ingredient in dairy cow diets should be carefully considered,  
32 as partial replacement, i.e., to corn silage (Colombini et al., 2010, 2012; Śliwiński et al., 2012).  
33 Sweet sorghum represents a particular cultivar with a high content of sugars (70-80% sucrose) and,  
34 to date, it has mostly been used in energy plant for ethanol and biofuel production. However, for its  
35 specific chemical profile, some seed companies have been promoting sweet sorghum as a possible  
36 crop for silage production and ruminant feeding. Over the last few years *in vitro* gas production  
37 (GP) technique has been largely adopted to evaluate fermentation of ruminant feeds, because it is a  
38 fast and cost-effective analysis (Rymer et al., 2005). To date, only the study of Di Marco et al.  
39 (2009) has explored the fermentative properties of sweet sorghum silage, when incubated *in vitro*  
40 with rumen fluid, in comparison with forage and grain genotypes. Thus, this research is aimed at  
41 comparing *in vitro* degradability, GP, and energy value of silages obtained from forage, sweet, and  
42 grain sorghum grown in two farms located in the Po Valley (Northern Italy).

## 43 **Material and methods**

44 Three hybrids of *Sorghum vulgare* spp. were used: a forage sorghum (Bulldozer), promoted for its  
45 high biomass yield and traded by KWS Italia Spa (Monselice, Padova, Italy), a sweet sorghum  
46 (Surgo) and a grain sorghum (Favorite), both traded by SIVAM Spa (Casalpuusterlengo, Lodi, Italy).  
47 Plants were grown in two pilot farms of the Veneto Agricoltura Agency, one (Farm 1) located in the  
48 province of Venice (Vallevecchia, latitude 45.6°N, longitude 12.9°E; 0 m above sea level) and one  
49 (Farm 2) located in the province of Rovigo (Ceregnano, latitude 45.0°N, longitude 11.9°E; 5 m  
50 above sea level). The farms were involved in a project aiming to evaluate quality of silages obtained  
51 from different genotypes of sorghum. In each farm, sorghums were sown in nine experimental plots  
52 (three plots per each hybrid) with an area of 0.2 ha each. Sowing took place in the first ten days of

53 June for all genotypes. No fertilizers were applied; urea (100 kg/ha) and herbicides were distributed  
54 at post-emergence phase. Irrigation of plants occurred only in Farm 2 (on July 2), as the Farm 1 is  
55 not equipped with an irrigation system. Sorghums were harvested on September 18, 2013 in Farm 1  
56 and on September 12, 2013 in Farm 2, in order to collect from both sites plants at a late-milk stage  
57 of maturity. The chemical composition of fresh forages was the following (expressed as mean value  
58 of the two farms): 24.6, 27.3, and 33.1% DM; 5.0% CP, 60.5% NDF, 6.1% starch, 6.1% ash, for the  
59 forage sorghum (Bulldozer); DM, 5.8% CP, 58.5% NDF, 9.2% starch, 6.2% ash, for the sweet  
60 sorghum (Surgo); % DM, 8.1% CP, 55.5% NDF, 21.0% starch, 6.6% ash, for the grain sorghum  
61 (Favorite). After harvest, three aliquots of chopped forage (10 kg each) were prepared for each  
62 hybrid, as a representative sample of the three experimental plots, homogeneously mixed, and  
63 mechanically compacted into nine laboratory mini-silos (3 silos×3 hybrids) with 20 l capacity,  
64 using a press equipped with a manometer and a hydraulic cylinder generating a compressive force  
65 of 1.2 atm/cm<sup>2</sup>. The mini-silos were hermetically closed and stored for 60 d at 24 ± 3°C. On  
66 opening the mini-silos, the upper layer (10-15 cm) of silage was discarded, to limit risk of taking  
67 samples with anomalous fermentation. After that, two aliquots (about 1.5 kg each) were prepared  
68 for each sorghum silage, as a representative sample of the three mini-silos. The same protocol was  
69 followed on both farms. The first aliquot of each silage was sent to the laboratories of ARAV  
70 (Breeders Association of Veneto Region, Padova, Italy) to assay proximate composition, pH,  
71 ammonia N content, and fermentation acid profile. Proximate analysis was conducted in triplicate  
72 according to AOAC (2012). The NDF fraction, inclusive of insoluble ash, was measured with  
73 Ankom<sup>220</sup> Fibre Analyzer (Ankom Technology, NY, USA). Ammonia N content and pH were  
74 determined by a potentiometer equipped with a specific electrode (pH meter BASIC 20, Crison  
75 Instruments, Alella, Spain). Fermentation acids were measured using a Thermo Finnigan Spectra  
76 System AS3000 auto-sampler (Thermo Electron Corporation, Waltham, MA, USA), equipped with  
77 an H<sub>2</sub>SO<sub>4</sub> 0.0025 N Bio-Rad HPX-87H column (Bio-Rad Laboratories, Richmond, CA, USA). The  
78 second aliquot of each silage was sent to the laboratories of the University of Padova. Once in the

79 laboratories, samples were dried in a forced-air oven at 60°C for 48 h, to determine DM content,  
80 and ground to 1-mm. Eight subsamples were prepared for each hybrid × farm combination and used  
81 for *in vitro* tests. Fermentations were conducted with Ankom<sup>RF</sup> gas production (GP) system  
82 (Ankom Technology, NY, USA). This system is a kit of bottles (310 ml) equipped with a pressure  
83 detector and wireless connection to a PC. Each bottle was filled with feed sample (0.500±0.0010 g),  
84 25 ml of rumen fluid, and 50 ml of buffer solution (ratio 1:2). Bottles were incubated at 39 ± 0.4°C  
85 for 48 h and vented at 3.4 kPa, to avoid overpressure conditions (Cattani et al., 2014). Two  
86 incubations were repeated in 2 successive weeks, and the following experimental design was  
87 applied: 3 hybrids×2 farms×4 replicates, plus 4 blanks (bottles without feed sample), giving a total  
88 of 28 bottles incubated in each of the two incubations. At the end of each incubation run,  
89 fermentation fluids were filtered into weighed crucibles (Robu Glasfilter-Geräte GMBH, Hattert,  
90 Germany) and treated with a heat stable amylase, but without sodium sulphite, to assay residual  
91 NDF, using a Fibertech Analyzer (VELP Scientifica, Milan, Italy). Rumen fluid was collected by an  
92 esophageal probe, as detailed by Tagliapietra et al. (2012), from three intact dry Holstein-Friesian  
93 cows fed hay *ad libitum* and 2.5 kg/d of concentrates. Buffer solution was prepared according to  
94 Menke and Steingass (1988). The degradability of NDF (NDFd) and of true DM (TDMd) were  
95 calculated as follows:

$$96 \text{ NDFd (\% NDF)} = [(NDF_{\text{feed}} - NDF_{\text{res}})/NDF_{\text{feed}}] \times 100$$

97 where  $NDF_{\text{feed}}$  is the NDF content (g/kg DM) of feed incubated;  $NDF_{\text{res}}$  is the amount (g/kg DM) of  
98 residual NDF

$$99 \text{ TDMd (\% DM)} = [(DM_{\text{feed}} - NDF_{\text{res}})/DM_{\text{feed}}] \times 100$$

100 where  $DM_{\text{feed}}$  is the DM content (g/kg) of feed incubated

101 Metabolizable energy (ME) content of silages was computed from chemical composition and NDFd  
102 measured at 48 h (NRC, 2001;  $ME_{\text{NRC}}$ ) or GP measured at 24 h of incubation (Menke and  
103 Steingass, 1988;  $ME_{\text{Menke}}$ ). The two equations were the following:

104  $ME_{NRC} \text{ (MJ/kg DM)} = -0.45 \times 4.184 + 1.01 \times DE$

105 where DE is the digestible energy:

106  $DE \text{ (MJ/kg DM)} = [(NDFd/1000) \times 4.2 + (tdNFC/1000) \times 4.2 + (tdCP/1000) \times 5.6 + (tdFA/1000)$   
107  $\times 9.5 - 0.3] \times 4.184$

108 where NDFd is the NDF degradability (g/kg NDF) measured at 48 h; tdNFC, tdCP and tdFA are the  
109 estimated true digestible contents of non-fibre carbohydrates, CP and EE (g/kg DM) calculated  
110 using the equations proposed by NRC (2001) (i.e., Eqs. 2–4a to 2–4e).

111  $ME_{Menke} \text{ (MJ/kg DM)} = 2.20 + 0.1357 \times GP_{24_{200}} + 0.0057 \times CP + 0.0002859 \times EE^2$

112 where  $GP_{24_{200}}$  is the gas production (ml) measured at 24 h and referred to 200 mg of feed sample;

113 CP = crude protein content (g/kg DM); EE = ether extract content (g/kg DM)

#### 114 *Statistical analysis*

115 Data of silage composition (proximate analysis, pH, fermentation acid profile, ammonia N) were  
116 subjected to analysis of variance using the general linear model procedure (PROC GLM) of SAS  
117 (SAS Institute Inc., Cary, NC, USA release 9.1). The statistical model considered effects of farm (2  
118 levels: Farm 1 and Farm 2), hybrid (3 levels: Bulldozer, Surgo, and Favorite), and interaction  
119 between farm and hybrid ( $F \times H$ ) as sources of variation. Other data (*in vitro* degradability, GP, and  
120 energy content of silages) were analyzed using a model that considered effects of farm, hybrid,  $F \times$   
121  $H$  interaction, and, in addition, incubation run (2 levels: incubation 1 and incubation 2) as sources of  
122 variation.

#### 123 **Results**

124 The DM content of silages was on average greater in Farm 2 compared to Farm 1 (29.0 vs. 25.5%,  
125 respectively;  $P < 0.001$ ; Table 1). The proximate composition of silages reflected the plant genotype.  
126 The forage sorghum had the greatest NDF, ADF, and ADL contents ( $P < 0.001$ ). On the other hand,  
127 the grain genotype showed the lowest fiber fraction, especially in Farm 1, and the highest starch  
128 content ( $P < 0.001$ ). As regards starch, the sweet genotype showed, on average, the lowest content in

129 Farm 1 and intermediate values in Farm 2. Starch content of the sweet sorghum was, on average,  
130 three times greater on Farm 2 than on Farm 1 (13.2 vs. 4.4% starch in Farm 2 and Farm 1,  
131 respectively). Final pH of silages was affected by farm, and hybrid ( $P < 0.001$ ; Table 2). In all silages  
132 lactate was the prevalent fermentation acid (on average 83.1% total fatty acids), followed by acetate  
133 (on average 16.7% total fatty acids); propionate was present only in traces and n-butyrate was never  
134 detectable by the GC. Total production of fermentation acids was influenced by hybrid ( $P < 0.001$ ),  
135 proving consistently lower for the forage genotype; in Farm 1 the sweet sorghum showed a lower  
136 acid production compared to the grain genotype, whereas the opposite tendency was observed in  
137 Farm 2 ( $P < 0.001$ ). The ratio between ammonia N and total N ranged from 2.97, for the sweet  
138 genotype of Farm 2, to 6.54% for the grain genotype of Farm 1. Values of NDFd were not  
139 influenced by hybrid and farm, and ranged from 50.2 to 57.3%, for the grain and the forage  
140 sorghums grown in Farm 1 (Table 3). Compared to the other two hybrids, the sweet sorghum  
141 revealed an intermediate extent of NDF degradability in the Farm 1 (NDFd=54.5%) and the lowest  
142 value in the Farm 2 (NDFd=51.7%). Irrespective of the farm, the grain genotype showed the  
143 greatest values of TDMd, whereas the lowest *in vitro* “true” DM degradability was found for the  
144 forage genotype. As observed for NDFd, the sweet sorghum exhibited intermediate values of  
145 TDMd with respect to other hybrids. As regards the sorghums of Farm 1, the grain genotype  
146 showed the greatest values of *in vitro* GP ( $P < 0.001$  and  $P < 0.05$ , at 24 and 48 h, respectively); no  
147 differences were found between the other two hybrids (the forage and the sweet), neither at 24 h nor  
148 at 48 h. A different ranking emerged for samples belonging to Farm 2, as the forage sorghum  
149 always had the lowest *in vitro* GP ( $P < 0.001$  and  $P < 0.05$ , at 24 and 48 h of incubation, respectively),  
150 whereas the sweet sorghum showed an *in vitro* GP comparable to that of the grain genotype. In  
151 terms of energy content the sweet sorghum tended to be more similar to the forage genotype in the  
152 Farm 1 and to the grain genotype in the Farm 2. Values of  $ME_{NRC}$  ranged from 8.9 (for the sweet  
153 genotype of Farm 1 and the forage genotype of Farm 2) to 10.1 MJ/kg DM (for the grain genotype  
154 of Farm 2). Values of  $ME_{Menke}$  were on average lower than those calculated using NRC (2001)



155 approach and ranged from 7.0 to 8.9 MJ/kg DM for the forage and the grain genotypes of Farm 1,  
156 respectively.

## 157 **Discussion**

158 Results of this study provide evidence that silages obtained from different sorghum hybrids differed  
159 in terms of chemical composition, fermentation profile and nutritional value. In addition, the  
160 cultivation site (farm) exerted a notable effect on silage characteristics. The DM content was largely  
161 affected by hybrid and farm. Firstly, the genotype could have exerted an effect, as observed by  
162 others (Pesce et al., 2000; Bolsen et al., 2003). Secondly, pedological characteristics of  
163 experimental plots could have influenced DM accumulation in sorghum plants. More precisely,  
164 soils belonging to Farm 1 were characterized, on average, by a lower OM, nitrogen, and mineral  
165 contents (i.e. phosphorus and potassium) compared to those of Farm 2. Thirdly, an effect also could  
166 be attributed to irrigation, which occurred only on Farm 2, where silages showed a greater DM  
167 content. Sorghum is known to be a drought resistant plant (Sanchez et al., 2002); however, some  
168 authors (Carmi et al., 2006) found that plants responded positively to irrigation, with an increment  
169 of DM accumulation. Chemical composition of silages reflected substantially the hybrid genotype,  
170 with a greater NDF content for the forage sorghum and a greater starch content for the grain one.  
171 Up to now, data concerning chemical composition of sweet sorghum genotypes are scarce.  
172 However, on the basis of our results, it could be speculated that irrigation promoted grain filling in  
173 plants of the sweet sorghum grown in Farm 2, which showed a starch content three times greater  
174 than the plants cultivated in Farm 1, where irrigation did not occur. In line with our expectations,  
175 chemical differences led to different fermentation patterns during the ensiling process. However,  
176 good visual appearance, colour and odour of silages seemed to indicate a proper preservation. In  
177 support of that, pH values of silages were included in the expected range (3.48-4.50) reported by  
178 Gallardo and Gagiotti (2004). Likewise, the ratio between ammonia N and total N was always  
179 under the threshold of 7, which indicates a correct preservation of silages (Romero, 2004).  
180 Moreover, fermentation acid profile, dominated by lactate and acetate, was an index of proper

181 ensiling into the mini-silos. Absence of significant effects due to the incubation run proves that the  
182 *in vitro* GP system used in this study has a satisfactory repeatability. The three sorghum genotypes  
183 showed different values of *in vitro* NDFd, and this confirmed data obtained *in vivo*, *in situ*, and *in*  
184 *vitro* by Di Marco et al. (2009). In line with previous findings (Pesce et al., 2000; Bolsen et al.,  
185 2003), the grain genotype showed the greatest values of TDMd and GP, as a result of greater starch  
186 content, whereas the forage sorghum showed the lowest values, as the fibrous fraction probably had  
187 a greater incidence on total DM degradability. In general, the sweet sorghum grown in Farm 1 had  
188 chemical characteristics and *in vitro* fermentative properties which were intermediate compared to  
189 the other two hybrids. However, the sweet sorghum seemed to be closer to the forage genotype in  
190 terms of DM and starch contents, *in vitro* GP, and energy value. Differently, the sweet sorghum  
191 grown in Farm 2 tended to be more similar to the grain genotype, especially in terms of *in vitro*  
192 fermentation properties and energy value.

193 The results of the present study would suggest that the cultivation and subsequent utilization of  
194 sorghum silages in ruminant feeding must necessarily consider the main peculiarities of each hybrid  
195 cultivated under different conditions. After ensiling, the sweet sorghum exhibited chemical  
196 characteristics and fermentative properties similar to those of the grain genotype, especially when  
197 plants were grown in irrigated fields. On this basis, silages obtained from sweet sorghum could be  
198 included in ruminant diets as total or partial replacement of corn silage, depending on the energy  
199 requirements of the animals. However, preliminary results presented in this paper should be  
200 validated *in vivo*.

201

## 202 **Acknowledgements**

203 This activity is part of Veneto Agricoltura Agency's project "Alternative crops rotation to contain  
204 diffusion of *Diabrotica virgifera virgifera* LeConte". The authors are grateful to the plant breeding  
205 companies, KWS Italia Spa and SIVAM Spa, for their kind support to the research, and to S. De  
206 Paoli (ARAV, Breeders Association of Veneto Region) for chemical analyses.

207 **References**

- 208 Association of Official Analytical Chemists (2012). Official Methods of Analysis, 19th ed., AOAC,  
209 Arlington, VA, USA.
- 210 Bolsen K.K., Moore K., Coblenz W.K., Siefers M.K., White J.S. (2003). Sorghum silage. In:  
211 Silage Science and Technology, L. Al-Amoodi (eds). Madison, WI, USA, pp. 609-632.
- 212 Carmi A., Aharoni V., Edelstein M., Umiel N., Hagiladi A., Yosef E., Nikbachat M., Zenou A.,  
213 Miron J. (2006). Effects of irrigation and plant density on yield, composition and *in vitro*  
214 digestibility of a new forage sorghum variety, Tal, at two maturity stages. Anim. Feed Sci. Technol.  
215 131: 120-132.
- 216 Cattani M., Tagliapietra F., Maccarana L., Hansen H.H., Bailoni L., Schiavon S. (2014). *Technical*  
217 *note: In vitro* total gas and methane production measurements from closed or vented rumen batch  
218 culture systems. J. Dairy Sci. 97: 1736-1741.
- 219 Colombini S., Galassi G., Crovetto G.M., Rapetti L. (2012). Milk production, nitrogen balance, and  
220 fiber digestibility prediction of corn, whole plant grain sorghum, and forage sorghum silages in the  
221 dairy cow. J. Dairy Sci. 95: 4457-4467.
- 222 Colombini S., Rapetti L., Colombo D., Galassi G., Crovetto G.M. (2010). Brown midrib forage  
223 sorghum silage for the dairy cow: nutritive value and comparison with corn silage in the diet. Ital. J.  
224 Anim. Sci. 9: 273-277.
- 225 Dann H.M., Grant R.J., Cotanch K.W., Thomas E.D., Ballard C.S., Rice R. (2008). Comparison of  
226 brown midrib sorghum-sudangrass with corn silage on lactational performance and nutrient  
227 digestibility in Holstein dairy cows. J. Dairy Sci. 91: 663-672.
- 228 Di Marco O.N., Ressia M.A., Arias S., Aello M.S., Arzadun M. (2009). Digestibility of forage  
229 silages from grain, sweet and bmr sorghum types: Comparison of *in vivo*, *in situ* and *in vitro* data.  
230 Anim. Feed Sci. Technol. 153: 161-168.
- 231 Gallardo M., Gagiotti M. (2004). La reservas y lo deseable, calidad en forrajes conservados. Manual  
232 de actualización técnica. Merco Láctea, San Francisco, Córdoba, Argentina.

233 Menke K.H., Steingass H. (1988). Estimation of the energetic feed value obtained from chemical  
234 analysis and gas production using rumen fluid. *Anim. Res. Dev.* 28: 7-55.

235 National Research Council (NRC) (2001). *Nutrient Requirements of Dairy Cattle*, 7th ed., National  
236 Academy Press, Washington, DC, USA.

237 Pesce D.M.C., Goncalves L.C., Rodrigues N.M., Borges I., Rodrigues J.A.S. (2000). Percentage  
238 and loss of dry matter and *in vitro* dry matter digestibility of 20 sorghum genotypes silages. *Arq.*  
239 *Bras. Med. Vet. Zootec.* 52: 250-255.

240 Romero L.A. (2004). *Ensilaje de soja, calidad en forrajes conservados*. Manual de actualización  
241 técnica, Merco Láctea, San Francisco, Córdoba, Argentina, pp. 40-41.

242 Rymer C., Huntington J.A., Williams B.A., Givens D.I. (2005). *In vitro* cumulative gas production  
243 techniques: History, methodological considerations and challenges. *Anim. Feed Sci. Technol.* 123-  
244 124: 9-30.

245 Sanchez A.C., Subudhi P.K., Rosenow D.T., Nguyen H.T. (2002). Mapping QTLs associated with  
246 drought resistance in sorghum (*Sorghum bicolor L. Moench*). *Plant Mol. Biol.* 48: 713-726.

247 Śliwiński B., Brzóška F., Węglarzy K., Malgorzata M. (2012). Effect of silage from maize and  
248 strip-cropped sorghum and maize on dairy cow's yield and milk composition . *Ann. Anim. Sci.* 12:  
249 367-379.

250 Tagliapietra F., Cattani M., Hindrichsen I.K., Hansen H.H., Colombini S., Bailoni L., Schiavon S.  
251 (2012). True dry matter digestibility of feeds evaluated *in situ* with different bags and *in vitro* using  
252 rumen fluid collected from intact donor cows. *Anim. Prod. Sci.* 52: 338-346.

254 Table 1. Chemical composition (% DM) of three sorghum silages harvested in the two farms

	DM	Ether extract	CP	NDF	ADF	ADL	Ash	Starch
Farm 1								
Forage	22.3 <sup>C</sup>	2.0 <sup>BC</sup>	8.2 <sup>BC</sup>	70.1 <sup>A</sup>	41.9 <sup>A</sup>	4.6 <sup>AB</sup>	6.9 <sup>AB</sup>	5.8 <sup>C</sup>
Sweet	22.8 <sup>C</sup>	2.1 <sup>BC</sup>	9.4 <sup>AB</sup>	62.1 <sup>B</sup>	34.7 <sup>B</sup>	3.7 <sup>BC</sup>	7.6 <sup>A</sup>	4.4 <sup>C</sup>
Grain	31.3 <sup>A</sup>	3.3 <sup>A</sup>	10.2 <sup>A</sup>	49.3 <sup>D</sup>	27.4 <sup>D</sup>	2.9 <sup>C</sup>	7.5 <sup>A</sup>	15.8 <sup>B</sup>
Farm 2								
Forage	26.7 <sup>B</sup>	2.1 <sup>BC</sup>	8.2 <sup>BC</sup>	72.0 <sup>A</sup>	42.3 <sup>A</sup>	5.2 <sup>A</sup>	5.6 <sup>C</sup>	4.6 <sup>C</sup>
Sweet	26.6 <sup>B</sup>	2.4 <sup>B</sup>	8.7 <sup>BC</sup>	57.2 <sup>BC</sup>	32.8 <sup>BC</sup>	4.4 <sup>AB</sup>	6.4 <sup>BC</sup>	13.2 <sup>B</sup>
Grain	33.6 <sup>A</sup>	1.6 <sup>C</sup>	7.8 <sup>C</sup>	54.9 <sup>C</sup>	30.3 <sup>CD</sup>	3.9 <sup>AB</sup>	6.5 <sup>BC</sup>	20.0 <sup>A</sup>
SEM <sup>1</sup>	0.73	0.18	0.32	1.00	0.62	0.26	0.25	0.89
Farm (F)	***	*	***	ns	ns	***	***	***
Hybrid (H)	***	Ns	*	***	***	***	**	***
F×H	ns	***	**	***	**	ns	ns	***

255 Contrast significance is indicated ns=non-significant; \*P≤0.05; \*\*P&lt;0.01; \*\*\*P&lt;0.001

256 A, B, C, D – values in columns with different letters differ significantly (P≤0.01).

257 <sup>1</sup>SEM = standard error of the mean

259 Table 2. Silage pH, total production of fermentation acids (FA; g/kg as fed), proportion of acetate  
 260 and lactate (% total FA), and proportion of ammonia N on total N (N-NH<sub>3</sub>/N; expressed as  
 261 percentage) of three sorghum silages harvested in the two farms

	pH	Total FA	Acetate	Lactate	N-NH <sub>3</sub> /N
Farm 1					
Forage	3.97 <sup>A</sup>	14.4 <sup>B</sup>	19.3 <sup>AB</sup>	80.7 <sup>DE</sup>	3.97 <sup>B</sup>
Sweet	3.89 <sup>AB</sup>	15.6 <sup>B</sup>	20.4 <sup>A</sup>	79.5 <sup>E</sup>	5.35 <sup>A</sup>
Grain	3.95 <sup>A</sup>	18.2 <sup>A</sup>	17.5 <sup>BC</sup>	82.4 <sup>CD</sup>	6.54 <sup>A</sup>
Farm 2					
Forage	3.74 <sup>CD</sup>	14.8 <sup>B</sup>	13.5 <sup>D</sup>	86.3 <sup>A</sup>	3.46 <sup>B</sup>
Sweet	3.62 <sup>D</sup>	17.9 <sup>A</sup>	14.1 <sup>D</sup>	85.6 <sup>AB</sup>	2.97 <sup>B</sup>
Grain	3.81 <sup>BC</sup>	17.3 <sup>A</sup>	15.6 <sup>CD</sup>	84.0 <sup>BC</sup>	3.64 <sup>B</sup>
<sup>1</sup> SEM	0.032	0.34	0.56	0.56	0.317
Farm (F)	***	Ns	***	***	***
Hybrid (H)	***	***	ns	ns	***
F×H	ns	***	**	***	**

262 Contrast significance is indicated ns=non-significant; \*P≤0.05; \*\*P<0.01; \*\*\*P<0.001

263 A, B, C, D, E – values in columns with different letters differ significantly (P≤0.01).

264 <sup>1</sup>SEM = standard error of the mean



266 Table 3. *In vitro* degradability of NDF (NDFd, %) and of true dry matter (TDMd, %), *in vitro* gas  
 267 production (ml/g DM), and metabolizable energy content (MJ/kg DM), calculated according to  
 268 NRC (2001; ME<sub>NRC</sub>) or to Menke and Steingass (1988; ME<sub>Menke</sub>), of three sorghum silages  
 269 harvested in the two farms

	NDFd	TDMd	Gas production		Energy value	
			24 h	48 h	ME <sub>NRC</sub>	ME <sub>Menke</sub>
Farm 1						
Forage	57.3 <sup>a</sup>	69.6 <sup>bc</sup>	156 <sup>B</sup>	220 <sup>B</sup>	9.1 <sup>ab</sup>	7.0 <sup>C</sup>
Sweet	54.5 <sup>abc</sup>	71.9 <sup>abc</sup>	181 <sup>B</sup>	236 <sup>B</sup>	8.9 <sup>b</sup>	7.8 <sup>BC</sup>
Grain	50.2 <sup>c</sup>	75.5 <sup>a</sup>	214 <sup>A</sup>	261 <sup>A</sup>	9.7 <sup>ab</sup>	8.9 <sup>A</sup>
Farm 2						
Forage	52.0 <sup>bc</sup>	68.5 <sup>c</sup>	177 <sup>B</sup>	237 <sup>B</sup>	8.9 <sup>b</sup>	8.0 <sup>AB</sup>
Sweet	51.7 <sup>bc</sup>	72.3 <sup>ab</sup>	219 <sup>A</sup>	278 <sup>A</sup>	9.6 <sup>ab</sup>	8.8 <sup>A</sup>
Grain	55.7 <sup>ab</sup>	75.9 <sup>a</sup>	216 <sup>A</sup>	273 <sup>A</sup>	10.1 <sup>a</sup>	8.6 <sup>AB</sup>
SEM	2.13	1.41	9.4	10.3	0.29	0.27
Incubation						
1	51.3	71.9	192	251	9.3	8.2
2	54.4	72.7	195	251	9.5	8.2
SEM	1.18	0.83	5.6	6.1	0.16	0.16
Farm (F)	ns	ns	*	*	ns	*
Hybrid (H)	ns	*	***	**	*	**
F × H	*	ns	ns	ns	ns	*
Incubation	ns	ns	ns	ns	ns	Ns

270 Contrast significance is indicated ns=non-significant; \*P≤0.05; \*\*P<0.01; \*\*\*P<0.001

271 a, b, c – values in columns with different letters differ significantly (P≤0.05).

272 A, B, C – as above for P≤0.01.

273 <sup>1</sup>SEM = standard error of the mean