Assessment of the nutritive value and production costs of hay and silage of brown middle rib sorghums

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In order to determine whether quality and production costs (PC) of the BMR (brown middle rib) silage are superior to those of this referred crop, two experiments were conducted. One was conducted with commercial BMR sorghum "Nutritop", and the other "Para Silo". Two treatments were established for each experiment with the same BMR sorghum (T_1 silage and T_2 deffered). Two plots of 70 ha were planted with each sorghum. In a half of each plot (35 ha) a silage of the whole plant was conducted and in the other half, it was left deffered. A completely randomized design with ten repetitions was used. The variables CP, DM digestibility, NDF, lignin, soluble carbohydrates and starch were analyzed. The digestibilities of those deffered were superior compared with the silages (65.5 vs 64.1 and 62.1 vs 60.1 for the 1° and 2° experiment, respectively). The soluble carbohydrates and starch were also superior ($P < 0.05$). No significant differences were found in the levels of CP and lignin. While the production costs of those diferred were very inferior (-546.15 %). The best quality of the silages may be explained by the high level of efluents generated, which sweep the soluble substances of high quality. The deffered BMR sorghums keep a superior quality, mainly energetic, apart from their low production costs, conditions that make them a good alternative for the dry season or cold weather.

Key words: *BMR sorghums, whole plant silage, deffered crop, nutritional quality, production costs*.

In the last years, new sorghums (*Sorghum bicolor* L.) with particular characteristics, called BMR (Brown Middle Rib) have been assessed in Argentina and other countries. These sorghums have three special genes (mutant BMR 6, 12 and 18). The first two (6 and 12) favor a lower deposit of lignin in the plant, polyphenol of very low or null ruminal degradation (Cordes 2008, Marinissen 2009, Kalan 2010 and Alessandri 2013).

As fresh forage, the BMR sorghums have higher quality in respect to the Sudan grass (*Sorghum bicolor* L.). Thay are superior in regards to the DM digestibility, energetic fractions (soluble carbohydrates and starch) and lower lignin levels. Great improvements in the productive and economic results have been proved with their use in cattle systems of different regions of the world (Aello and Dimarco 2004, Berti 2010 and Murray *et al*. 2010).

A similar phenomenon occurs with the silage of the whole plant of BMR sorghum (Marinissen 2010, Díaz *et al*. 2012 and Guzmán González and Fonseca Jiménez 2013). Good results have been obtained with this silage, in respect to nutritional quality and the meat and milk productions (Giorda and Cordes 2005, Romero 2008 and Marinissen and Melin 2009). However, the information about its quality and production costs when using it as deffered forage is scarce. The deffered crop is that dried by the effect of the frosts or strong draughts, and the forage is transferred to another season, especially to autumn-winter or the dry season.

From considering this information, an experiment was designed to determine whether the nutritional quality and the production costs of the silage of the whole plant BMR sorghum are superior to those of this deffered crop.

Materials and Methods

This study was conducted during the autumn and winter of 2010 in Cabildo locality (Buenos Aires, Argentina). The predominating soils in the area are the typical argiudol very superficial (Project PNUD ARG 85/019- INTA. 1989).

Two experiments were conducted in this place, with two treatments each. In each experiment, a defferent commercial BMR sorghum was assessed. In the first, the commercial BMR sorghum called "Nutritop" (Advanta SA Enterprise) was used and in the second, the "Para Silo" (Alianza Semillas SA Enterprise). Two treatments with the same sorghum were assessed: silage (T_1) and deffered (T_2).

Two plots of 70 ha each were planted with the BMR sorghums. The sowing date was November 28th, 2010. The harrowing disc and the sowing with fine grain sowing machine were applied. Neither fertilizers nor herbicides were used. In a half of each plot (35 ha), a silage of whole plant was conducted with fine particles (1.5-2.0 cm length), using a polyethylene bag (4.5 m width, 50 m length and 200 microns thickness). In the other half, it was left as deffered crop without cutting (figure 1).

Ten sub-samples (repetitions) were obtained from each treatment through a random sampling. The T_1 samples were taken from the silage and those of T_2, from the deffered (dry) in the same date (June 15th, 2010). The size of each sample was of 0.5 kg of DM, and each of

Figure 1. Tests under study

them was placed in a nylon bag with the corresponding identification. The samples were preserved in a fridge-freezer (-5°C) until getting to the lab. All the sub-samples were taken to the INTA Bordenave lab (Buenos Aires), to conduct the chemical analyses.

The DM, CP and starch were determined according to AOAC (1995). The DM *in vitro* digestibility was calculated in agreement with the method of Tilley and Terry (1963), modified as direct acidification method (Ankom Technology 2008). The Antrona method (Silva *et al*. 2003) was followed for the soluble carbohydrates. The NDF was determined according to van Soest (1994), using an ANKOM equipment, and in the case of lignin, he criteria of Goering and van Soest (1970) were applied.

The direct production costs (PC) were determined in this study as part of a partial budget to separate the “fixed” direct costs from the “variable” ones (Oliverio 2010 and Martínez Ferrario 2010). The mean values of the last five years were used to determine the production costs, according to the Argentinan market (USD ha^{-1}).

Direct cost (USD ha^{-1})

- Labouring: 53.0
- Seed: 20.0
- Silage (machine and cover): 500.0

Total cost of the silage: 573 USD ha^{-1}

Total cost of the deffered: 73.0 USD ha^{-1}

The data analysis of nutritional quality was conducted with an ANOVA, with a completely randomized design with ten repetitions. The statistical analysis of the chemical parameters was conducted according to the SAS/STAT (2005), using the GLM procedure. The analyzed variables were: CP, DM digestibility, NDF, lignin, soluble carbohydrates and starch.

Results and Discussion

The sorghums with BMR trait have reduced lignin content in 40-50% in leaves and stems. This determines as average 7-10 extra percent points in digestibility values, in respect to the sorghums that don’t have BMR gens. This performance was observed especially when they were consumed as fresh forages (Torrecilla 2006 and Carrasco *et al*. 2009).

Meanwhile, the same does not occur in the silages, as great part of the digestible nutrients (soluble carbohydrate, CP and starch) determining the DM digestibility are lost easily during the silage process (fermentations) and throughout the effluents (Romero *et al*. 2008 and Fernández Mayer 2012).

Table 1 presents the results of the chemical analysis of the silages and those of the deffered (hay en pie) of BMR sorghums in both tests.

The DM digestibility of the BMR sorghum (“Nutritop” in the first test) showed a light tendency ($P > 0.10$) in favor of the deffered, compared with that of the silage (table 1). Meanwhile, in the second test (BMR “Para Silo”), the digestibility of the deffered was significantly higher ($P < 0.01$).

During the silage process, some nutritional indicators were modified. They are product of the effluents, mainly caused by the high water contents (+ than 75%) the BMR sorghums have on their tissues up to the first reproductive phases (milky-sticky grain) (Fernández Mayer and Vitali 2005 and Marinissen and Melin 2009).

In an immature crop (< 28 % DM), during the chopping and in the first weeks of silage, the lack of oxygen breaks the cell membranes, making easier the exit of the cell content (Cummins *et al*. 2007 and Bras 2010). High amounts of effluents have been measured during the silage process (+ than 200 L t^{-1} of fresh forage) (Marinissen 2010 and Bernardes 2012). Apart from the losses of nutrients through the effluents, the immature sorghum has lower energy concentration, due to the lower yield of the grain. This provokes the low level of starch and high proportion of CP, composed by non-protein nitrogen (NPN) in more than 70 % (Gallardo 2008).

The losses due to lixiviation (effluents) depend on the humidity content of the silaged forage, the compactness degree, the fermentations of the whole plant silages, the type of silo (bunker, cake or bridge and silo-bag) and the previous treatment of the forage (Martínez Fernández and Delgado 1998).

From the practical point of view, there are three effective forms to increase the DM levels up to 30-35 % of the forage and reduce the losses. A pre-drying (pre-withering) previous to the forage (Fernández Vázquez 2000) and the cutting-chopping of the material to the stage of sticky grain to hard may be delayed (Bragachini *et al*. 1997). In both options, especially the second, the silage quality is significantly reduced (Marinissen *et al*. 2009). The third option consists of leaving the forage to dry off in the paddock (deffered) due to frosts or strong draughts (Fransen and Strubi 1998and Fernández Mayer

Table 1: Nutritional quality of silages vs deffered of sorghums BMR (%)

	Material	DM	CP	DMD	NDF	Lignin	NSC	Starch	pH
First test	T_1 silage “Nutritop”	27.8	4.8	64.1	63.5	4.0	5.2	3.6	4.15
	T_2 deffered “Nutritop”	88.6	4.9	65.5	64.6	3.0	11.6	4.4	-------
	SE (±) Sign.	-----	0.18 NS	0.71 NS	0.95 P < 0.01	0.04 NS	0.52 P < 0.001	0.225 P < 0.05	------
Second test	T_1 silage “Para Silo”	26.6	7.3	60.1	67.0	3.7	1.0	9.6	4.62
	T_2 deffered “Para Silo”	54.2	7.2	62.1	62.6	3.0	10.9	11.3	--------
	SE (±) Sign.	------	0.25 NS	0.27 P<0.01	0.61 P< 0.01	0.10 NS	0.21 P<0.05	0.31 P<0.05	------

2012).

When frosts occur (-0°C), the frozen rate is low and the ice crystals, which are few, grow widely. This situation breaks the cell and the water is lost due to diffusion through the plasmatic membranes, provoking a total or partial collapse of the cell.

The ice formation in the inter-cell spaces provokes the drying out of the cells, keeping inside them high proportion of total solids, even great part of soluble solids. Besides, the plant digestibility also increases (Toledo Vivas 2011). This would explain the higher quality of the deffered sorghum of both tests, obeying to the frosts effect (table 1).

In a study of Bolleta *et al*. (2010), differential effect of the frost on the quality of two different sorghums (*Sorghum bicolor* L.), BMR and Sudan was proved. Both crops received a strong frost (-7°C) five days before silage (figure 2). Under these conditions, the effluent losses would significantly reduce, and the digestible DM would increase (Alende *et al*. 2007 and Coria 2010). In this test, the DM digestibility of the BMR silage was superior (75.10 %) to that of the Sudan sorghum (62.0 %) (P < 0.01). This is due to the effect of the BMR genes, which promote higher nutrients concentration (Giorda and Cordes 2009).

In respect to the DM production costs (USD per kilo of MS^{-1}), the deffered sorghum was 546.15 % inferior compared with the silage of the whole plant (table 2).

It is concluded that the deffered BMR sorghums had, in both tests, higher quality. The DM digestibility of the second test was significantly superior (P < 0.01) and a tendency (P > 0.10) in the first test. Meanwhile, the levels of soluble carbohydrates and starch were higher in both BMR sorghums (P < 0.05). No significant differences were found in the levels of CP and lignin. In the mean time, the production costs of the deffered sorghums were inferior (-546.15 %).

The results of this study are a new alternative for regions affected by environmental factors (draughts or cold climate and frosts) or any other inclemency limiting the quality and amount of silages. From them, a technology (deffered crop) with the new BMR sorghums

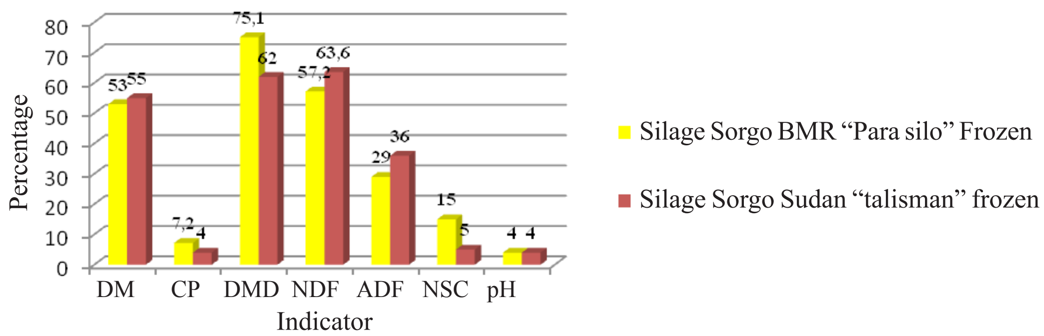

Figure 2. Bromatological quality of BMR sorghums silages and of the Sudan type “frozen” (Bolletta *et al*. 2010).

Table 2. DM production cost

Indicator	Silage of the whole plant	Deffered (Standing hay)
Cost of the BMR sorghum	573.0 USD ha^{-1}	73.0 USD ha^{-1}
Mean production per ha	8.500 kg MS ha^{-1}	8.500 kg MS ha^{-1}
DM losses per ha	±20.0%	±35.0%
Costs per DM kilo	0.084 USD kg. MS^{-1}	0.013 USD kg MS^{-1}

may be developed in order to obtain a forage reserve of good quality available for all cattle producers. The use of this technique is possible due to its low production cost, even in those cattle exploitations with low economic and financial resources.

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