Revista Brasileira de Zootecnia
© 2015 Sociedade Brasileira de Zootecnia
ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., 44(9):303-313, 2015

Production technology and quality of corn silage for feeding dairy cattle in Southern Brazil

Mábio Silvan José da Silva[1], Clóves Cabreira Jobim[2], Edson Carlos Poppi[3], Tamara Tais Tres[1], Milene Puntel Osmari[1]

[1] *Universidade Estadual de Maringá, Programa de Pós-graduação em Zootecnia, Maringá, PR, Brasil.*
[2] *Universidade Estadual de Maringá, Departamento de Zootecnia, Maringá, PR, Brasil.*
[3] *Lallemand, Maringá, PR, Brasil.*

ABSTRACT - The objective of this study was to evaluate the production practices and use of corn silage in dairy farms in Southern Brazil, and to evaluate their impact on the nutritional quality and occurrence of mycotoxins. The data were collected by application of questionnaires among the producers, and by analysis of silage samples. The variables were subjected to factorial analysis of data reduction through the principal components method, thus obtaining 84.12% of the variance associated with the location, corn hybrid, crop production management, and inoculant used, characterizing the farms into four distinct groups. In farms from Paraná, the silage production technologies were more associated with implantation and crop management processes, and investment in equipment related to ensilage/silo feed-out was less frequent. Farms of Rio Grande do Sul showed high adoption of outsourced services, self-propelled machines, bunker silos, double-sided plastic film, and inoculant to control aerobic deterioration, and the silages showed higher levels of propionic acid (7.95 g/kg DM), and lower concentrations of aflatoxins (7.7 ppb) and total mycotoxins (26.58 ppb). The farms evaluated in Southern Brazil have good production efficiency and corn silages with excellent quality, regardless of their production characteristics.

Key Words: clustering, inoculant, maize, mycotoxins, silage production

Introduction

Corn silage is used as an energy and fiber source for cattle, mainly for dairy cows (Borreani and Tabacco, 2010; Bernardes, 2012). This means that it is necessary to improve the nutritional value of the silage to decrease the participation of the concentrate in the diets, without affecting the physiology and performance of the animals.

The quality of silage depends on a range of factors, which can change its extension and fermentation patterns. Jobim and Nussio (2014) proposed that the main effects are those that are influenced by the ensiled crop characteristics. Despite the crop-inherent factors, it is important to ensure that the silage is properly sealed, avoiding soluble compound losses and development of fungi responsible for production of mycotoxins.

The nutritive value of the corn silage depends on the hybrid, crop density, growing conditions, degree of maturity and moisture of the crop when harvested, and ensilage conditions (Satter and Reis, 2012). Physical characteristics such as average particle size and density are directly associated with the fermentation type and its extension in the silage, and silage aerobic stability is the major factor that will determine the roughage quality. The production of silage with a low density due to high average particle size favors consumption of soluble carbohydrates, low production of organic acids, and higher final pH (McDonald et al., 1991). A low density will also lead to higher porosity and air infiltration in the silage panel, resulting in lower aerobic stability and more losses during the post-opening period (Jobim et al., 2007).

Applying inadequate management practices during crop growing, ensilage design, and silo emptying may lead to poo-quality silage and development of fungi and associated mycotoxins. Aflatoxins and zearalenone deserve to be mentioned due to their estrogenic effect in domestic animals, leading to lower milk production, repetition of estrus, low conception rate, and abortion (Sassahara et al., 2003).

There are many factors in the different production systems that can be modified to obtain lower qualitative and quantitative losses in silages, and consequently lower cost of feed and higher productive and sanitary rates for the herd.

The aim of this study was to evaluate the main practices used during the process of production and utilization of corn

Received March 6, 2015 and accepted June 29, 2015.
Corresponding author: ccjobim@uem.br
http://dx.doi.org/10.1590/S1806-92902015000900001

silage, the impact of production systems on silage quality, and adoption by dairy farms in Southern Brazil.

Material and Methods

The study was conducted on dairy farms from the south of Brazil. The first step was to visit 40 dairy farms, located in the states of Paraná, Santa Catarina, and Rio Grande do Sul. The farms were selected with the support of technicians from cooperatives that were responsible for the studied region.

The survey data regarding the farms, practices of production, and utilization of silages were obtained through questionnaires filled in by the producers during visits to farms. The questionnaire consisted of questions regarding the form of silage production, as well as qualitative and quantitative data of the culture and silo (Tables 1 and 2).

The silo dimensions were obtained using a tape-measure, and the temperature of the silage was measured by evaluating the surface superior, medium, and basal layers using a digital thermometer (Gulterm 1001). Each temperature was measured three times by inserting the thermometer to a depth of 10 cm on the silo face. The ambient temperature was also taken. Using an infrared thermography camera (Model Flir i5), images of the silo were also captured and processed.

To determine the silage density, a cylinder (5.6 cm diameter × 50 cm length) with a serrated cutting edge was used to obtain twelve samples at different points on the face of the silo. Subsamples were homogenized to obtain a composite silo sample, and 1.5 kg of each silo sample was packed into plastic bags to avoid exposure to air. The samples were stored in coolers with chemical ice for transportation to the laboratory, and pH values were measured using a potentiometer (Kung Jr. et al., 1984).

To determine the average particle size (APS), the Penn State University methodology adapted by Mari and Nussio (2002) was used. The total, whole, and broken corn grains were determined from the fractions of silage retained in upper and lower mesh sieves (8 mm).

The content of dry matter (DM), mineral matter (MM), and crude protein (CP) from composite silo samples was determined in the laboratory following the Silva and Queiroz (2002) methods.

Subsamples weighing approximately 0.15 kg were removed from the composite sample, vacuum-packed, and properly stored and kept frozen to send to the laboratory,

Table 1 - Characterization of farm groups by categorical variable on pre-silage processes (deployment and crop growing) and coefficient of variation (CV), represented in percentage (%)

Indicator		Group				Overall mean	CV (%)
		1	2	3	4		
Farm/group		40.0	20.0	30.0	10.0	100.00	-
Location	Paraná	100.0	87.5	8.3	0.0	60.0	47.7
	Santa Catarina	0.0	12.5	50.0	25.0	20.0	
	Rio Grande do Sul	0.0	0.0	41.7	75.0	20.0	
Hybrid company	Agroman	18.8	12.5	0.0	0.0	10.0	70.4
	Agroceres	0.0	0.0	8.3	0.0	2.5	
	Agroeste	0.0	0.0	41.7	25.0	15.0	
	Biogênese	12.5	0.0	0.0	0.0	5.0	
	Biomatrix	0.0	0.0	0.0	25.0	2.5	
	Coodetec	0.0	0.0	8.3	0.0	2.5	
	Dekalb	0.0	0.0	16.7	0.0	5.0	
	Dow Agroscience	0.0	0.0	8.3	0.0	2.5	
	Pioneer	31.3	75.0	8.3	0.0	30.0	
Hybrid choice criteria	Productivity	25.0	12.5	33.3	50.0	27.5	43.7
	Nutritive value	25.0	12.5	33.3	0.0	22.5	
	P+NV	12.5	25.0	8.3	0.0	12.5	
	Others	37.5	50.0	25.0	50.0	37.5	
Crop management	DS	18.8	25.0	0.0	0.0	12.5	50.0
	CF	6.3	12.5	0.0	0.0	5.0	
	OF	18.8	0.0	0.0	0.0	7.5	
	DS+CS	0.0	0.0	91.7	50.0	32.5	
	DS+OF	6.3	12.5	0.0	0.0	5.0	
	DS+CF+OF	31.3	37.5	8.3	50.0	27.5	
	DS+fertigation	6.3	0.0	0.0	0.0	2.5	
	CS+OF	12.5	12.5	0.0	0.0	7.5	

P - productivity; NV - nutritive value; DS - direct seeding; CF - chemical fertilizer; OF - organic fertilizer.

Table 2 - Characterization of farm groups by categorical variable on silage/silo emptying processes and coefficient of variation (CV), represented in percentage (%)

Indicator		Group				Overall mean	CV (%)
		1	2	3	4		
Crop age at cutting	<4 months	37.5	25.0	33.3	25.0	32.5	37.8
	4 months	50.0	62.5	41.7	50.0	50.0	
	>4 months	12.5	12.5	25.0	25.0	17.5	
Silage production	Own	56.3	50.0	58.3	0.0	50.0	33.8
	Outsourced	43.7	50.0	41.7	100.0	50.0	
Harvester	Pull-type	50.0	50.0	66.7	0.0	50.0	33.8
	Self-propelled	50.0	50.0	33.3	100.0	50.0	
Silage machine maintenance	Silage beginning	6.3	0.0	0.0	0.0	2.5	8.0
	Daily	93.8	100.0	100.0	100.0	97.5	
Storage time	<1 month	25.0	12.5	8.3	0.0	15.0	41.3
	1 to 2 months	18.8	37.5	50.0	0.0	30.0	
	>2<3 months	0.0	0.0	0.0	0.0	0.0	
	≥3months	56.3	50.0	41.7	100.0	55.0	
Silage additive	Present	50.0	100.0	50.0	100.0	65.0	35.8
	Absent	50.0	0.0	50.0	0.0	35.0	
Inoculant	Lalsil	0.0	100.0	0.0	100.0	30.0	61.4
	Biomax	12.5	0.0	33.3	0.0	15.0	
	Sil-All	12.5	0.0	0.0	0.0	5.0	
	Nitral	0.0	0.0	8.3	0.0	2.5	
	Not specified	25.0	0.0	8.3	0.0	12.5	
	Absent	50.0	0.0	50.0	0.0	35.0	
Silo type	Stack	12.5	0.0	33.3	0.0	15.0	19.5
	Bunker	87.5	100.0	66.7	100.0	85.0	
Plastic film	Black	18.8	0.0	0.0	0.0	7.5	13.9
	Black-on-White	81.3	100.0	100.0	100.0	92.5	
Weight on the plastic	Sand	56.3	50.0	75.0	50.0	60.0	74.6
	Tires	25.0	12.5	8.3	50.0	20.0	
	Sugarcane bagasse	0.0	25.0	0.0	0.0	5.0	
	Sand and tires	6.3	12.5	0.0	0.0	5.0	
	Others	12.5	0.0	8.3	0.0	7.5	
	None	0.0	0.0	8.3	0.0	2.5	
Feed-out method	Manual	50.0	37.5	33.3	25.0	40.0	31.0
	Machine	50.0	62.5	66.7	75.0	60.0	
Discard silage	≤5 cm	31.3	25.0	25.0	0.0	25.0	51.9
	>5≤10 cm	50.0	37.5	25.0	75.0	42.5	
	>10≤20 cm	6.3	12.5	41.7	0.0	17.5	
	≥30 cm	0.0	12.5	8.3	0.0	5.0	
	None	12.5	12.5	0.0	25.0	10.0	
Feed-out rate/day	10-19 cm	31.3	25.0	33.3	0.0	27.5	44.8
	20-29 cm	12.5	12.5	25.0	25.0	17.5	
	30-39 cm	31.3	50.0	16.7	75.0	35.0	
	≥40 cm	25.0	12.5	25.0	0.0	20.0	
Compositional analyses	Yes	43.8	50.0	41.7	50.0	45.0	32.5
	No	56.3	50.0	58.3	50.0	55.0	
Frequency of dry matter evaluation	Opening	37.5	25.0	25.0	25.0	30.0	47.4
	Weekly	6.3	12.5	8.3	0.0	7.5	
	Monthly	0.0	12.5	8.3	0.0	5.0	
	Never	56.3	50.0	58.3	75.0	57.5	
Silage limitations	Weather	25.0	25.0	0.0	0.0	15.0	56.1
	Machinery	12.5	25.0	8.3	0.0	12.5	
	Labor	18.8	12.5	50.0	0.0	25.0	
	Packing	0.0	12.5	8.3	0.0	5.0	
	Sealing	6.3	0.0	0.0	0.0	2.5	
	Crop quality	6.3	0.0	0.0	0.0	2.5	
	None	31.3	25.0	33.3	100.0	37.5	
Technical assistance	Yes	56.3	75.0	50.0	25.0	55.0	34.7
	No	43.8	25.0	50.0	75.0	45.0	

where ELISA (enzyme-linked immune sorbent assays) were carried out to identify whether aflatoxin and zearalenone were present.

To extract the juice from the silage, 0.5 kg of each subsample was thawed and pressed in accordance with Silva and Queiroz (2002). Then, the juice was frozen and stored until the organic acid analysis. The method used to determine the organic acids was gas chromatography (Shanta and Napolitano, 1992).

After the data collection, 31 indicators were obtained, which were grouped into three different categories: farm profile; production technology; and silage management and silage characteristics. These categories were subjected to factor analysis by principal components analysis and to hierarchical classification.

Eleven indicators were used to express the farm profile: location (Paraná, Santa Catarina, Rio Grande do Sul), farm area, total number of animals, number of dairy cows, number of dry cows, number of silos, productive activity (dairy, beef cattle, double aptitude, others), technical assistance (yes or no), silage compositional analysis (yes or no), silage dry matter evaluation frequency (weekly, monthly, never), and silage limitations (weather, machinery, labor, packing, sealing, crop quality, none).

For the production-technology category, ten indicators were used: silage production (own or outsourced), silage machine type (pulled by tractor or self-propelled), silage machine maintenance (silage beginning, daily), corn hybrid used (17 hybrids), hybrid company (Pioneer, Agroman, Coodetec, Biogênese, Agroeste, Dekalb, Agroceres, Dow Agroscience, Biomatrix), crop management (direct seeding, chemical fertilizer, organic fertilizer, direct seeding with both chemical and organic fertilizer, direct seeding and organic fertilizer, direct seeding with fertigation, chemical and organic fertilizer, direct seeding and chemical fertilizer), additive usage (yes or no), inoculants used (Lalsil, Biomax, Sil-All, Nitral, not specified, none), crop age during the silage (<4 months, 4 months, >4 months), and hybrid choice criteria (productivity, nutritive value, productivity and nutritive value, others).

Another ten indicators were associated with silage management and silage characteristics: silo type (stack, bunker), silo size, amount of silage/silo, plastic film (black or black-on-white), weighing down of the plastic film cover (sand, tires, sugarcane bagasse, sand and tires, others, none), silo feed-out method (manual or machine), storage time (<1 month, 1-2 months, >2<3 months, ≥3 months), average silage yield, silage disposal (≤5 cm, >5≤10 cm, >10≤20 cm, ≥30 cm, none), and feed-out rate/day (10-19 cm, 20-29 cm, 30-9cm, ≥40cm).

From a matrix of 40 farms and 31 indicators, 18 indicators were selected that showed a coefficient of variation (CV) higher than 45%. These indicators were: location, farm area, total number of animals, number of dairy cows and number of dry cows, number of silos, frequency of silage dry matter evaluation, silage limitations, silage machine type, hybrid company, crop management, inoculants used, silo size, amount of silage/silo, weighing down of the plastic film cover, average silage yield, silage disposal, and feed-out rate/day. From these, the total number of animals, number of dairy cows, and number of dry cows were excluded for presenting a correlation factor higher than 75% when compared with farm area. Using the same criteria, the indicator amount of silage was excluded for its correlation with silo size ($r = 0.899$; $P<0.05$).

The remaining 14 indicators were subjected to factorial analysis of data reduction using the principal components (PC) method, selecting the factors according to their associated values when >1. In this way, 70.16% of the variance was explained through five indicators: location, silage machine type, hybrid company, crop management, and inoculants used.

A second analysis was made by deleting the silage machine type indicator, aiming to obtain a more expressive value for the variance explanation, resulting in 84.12% of explained variance and two principal components.

The principal components were subjected to grouping analysis using the Ward methodology (1963), thus obtaining groups with common characteristics. The groups were subjected to variance analysis, and the differences between the means were analyzed by the Tukey test ($\alpha<0.05$) for the variables regarding the physical and chemical characteristics of silages using the Statistical Package for the Social Sciences (SPSS, version 17.0) software.

Results and Discussion

The principal component (PC) values used for the group analysis were 2.38 and 0.98 for the principal components one and two (PC1 and PC2), which explained 59.6% and 24.5%, respectively, of the original total variance of 84.1% (Table 3).

The first component (PC1) characterizes the factors regarding farm dimension (ha) and crop management for ensilage, represented by the indicators of location (state/weather conditions), hybrid company, and crop management. The second component (PC2) responds to production technology indicators and silage management represented by the inoculants used.

According to the statistical criteria adopted, it was possible to observe that the corn crop growing has more influence on silage quality than the ensilage and silo feed-out processes. This occurs because it is easier to control the ensilage/silo feed-out processes than the growing of crops. The growing of crops depends on many factors, mainly those regarding weather conditions, which are hard or even impossible to control.

In the ensilage process, the chemical composition and harvest of the crop represent the major impact factor, as the composition is influenced by crop maturity, chemical compounds present, crop management, plant microbiology, and local environmental conditions.

As a result of the cluster analysis, four distinct groups were obtained and ranked according to their similarity characteristics, and then arranged on the two component axes (Figure 1). The major number of farms was characterized by group 1, representing 40% of the total. Group 2 was responsible for 20% of the farms; group 3 represented 30%; and group 4 had the lowest amount, corresponding to 10%.

We observed that 100% of the farms arranged in group 1 were located in Paraná state, while 100% of the farms of group 4 were located in the states of Rio Grande do Sul and Santa Catarina, which were those that most invested in ensilage/silo feed-out processes, along with group 2 (Paraná and Santa Catarina).

Among the visited farms, different criteria were adopted to choose the corn hybrid: in 27.5%, productivity was the priority, 22.5% nutritive value, and only 12.5% both characteristics (Table 1). These data show that the top priority in the south of Brazil is productivity, while in the whole country it is 18.38% and 32.72% for nutritive value and silage production, respectively (Bernardes, 2012). Silages were produced using 17 different corn hybrid crops. Among the declared corn hybrids, 30% were sold by Pioneer, with major inset in groups 1 and 2, representing 31.3% and 75.0%, respectively (Table 1). High usage of Pioneer hybrids (53%) was also observed by Carvalho and Jobim (2014) in the central-eastern region of Paraná. However, 25% of the producers did not know which hybrid was used in the evaluated crop.

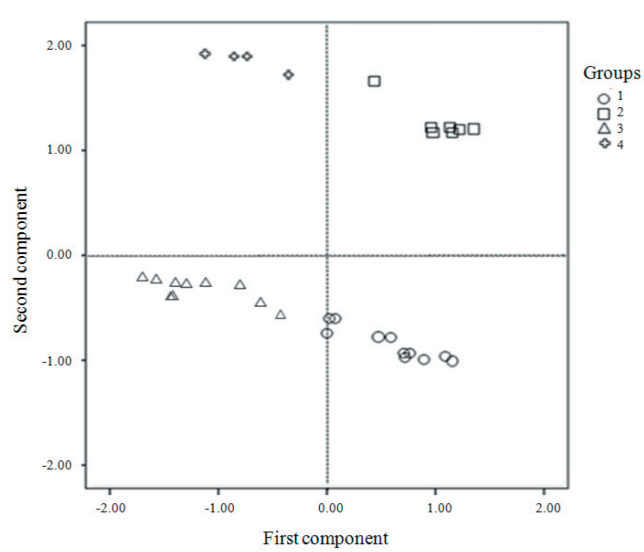
In all studied farms, some kind of technology was applied in crop growing management, which includes the direct seeding that is used in 80% of the cases. Among them, 33% applied organic fertilizer and 60% used chemical fertilizer + organic fertilizer. Furthermore, 100% of the farms included in groups 3 and 4 employed the use of chemical fertilizer (Table 1). Only 27.9% of the Brazilian producers adopted any kind of technology in agricultural management related to crops.

Regarding the ensilage/silo feed-out processes factors (Table 2), it was observed that 50% of the producers outsourced silage production, which also used self-propelled machines. Group 4 stands out as all silages were outsourced and crop harvesting was made with self-propelled harvesters. All the other groups were equal in own or outsourced silage production. The scenario highlights the greater use of technology in the southern region when compared with the whole country, where only 41.2% outsource their silage production, and only 9.6% use a self-propelled harvester (Bernardes and Do Rêgo, 2014).

In general terms, all producers cared about the ensiling machine maintenance, and 97.5% performed maintenance daily, which is above the national rate of 54.4% (Bernardes, 2012). Sharpening the knives is recommended for every 100 t of green mass harvested, in a minimum basis, and the regulation of counter knives is at every 500 t, since

Table 3 - Vectors (weights) for each one of the four variables according to the two principal components (PC) used for group analyses

Variable	PC 1	Significance	PC 2	Significance
Location (state)	0.911	0.000	–0.254	-
Hybrid company	0.850	0.000	–0.025	-
Crop management	0.867	0.000	–0.022	-
Inoculant used	0.284	-	0.956	0.000
Explained variance (%)	59.6		24.5	
Accumulated variance (%)			84.1	



First component - higher values indicate better farm location (favorable climatic conditions), use of hybrid corn indicated silage and adoption of better production management techniques. Second component - high values indicate the use of more effective inoculants in the silage quality.

Figure 1 - Spatial distribution of farms according to the two principal components.

the Brazilian machines used to harvest forage show low efficiency and need for constant maintenance, according to Novaes et al. (2004). In this context, the use of outsourced services to produce silage is becoming popular nationwide and enables the harvesting with the proper high-technology machines, guaranteeing high yield, favoring the right length of harvest and faster silage sealing without huge investments (Pereira, 2011).

Regarding the stocking structures, we observed that the bunker silo was the most popular among the groups, as well as the black-on-white plastic film, which reached 85% and 92.5%, respectively (Table 2). The same observation was noted by Carvalho and Jobim (2014), who recorded that bunker silos and black-on-white plastic film are the most used types in the central-eastern region of Paraná State, with values of 75% and 41%, respectively. In the whole country, Bernardes and Do Rêgo (2014) observed values of 60.4% and 77.7%, respectively, which is below the values found in this study regarding the southern region.

Despite the contamination risk, upon silo opening, sand/soil was the material most often used for covering and protection of the plastic film on 60% of the farms. Similar conditions were observed in Brazil (69.2%) by Bernardes and Do Rêgo (2014), and higher levels were observed in the central-eastern region of Paraná State (85%). Bernardes (2012) found that tires were the second most used material, as in the southern region. However, the level was lower in the southern region (20%), and more common in silos within group 4 (50%; Table 2).

Inoculants were applied in 65% of the silages evaluated, and in groups 2 and 4 the percentage reached even 100%. According to Bernardes and Do Rêgo (2014), only 27.7% of Brazilian producers use additives in silage. Among the southern farms, Bernardes et al. (2012) reported that only 18% of the additives are bacterial inoculant.

Regarding the silo opening and post-opening phases, it was found that in 60% of the farms the silo feed-out was carried out using machines. The manual unloading was more expressive in group 1, representing 50% (Table 2). This percentage is lower than that observed in Brazil (85%), according to Bernardes and Do Rego (2014). In accordance with Carvalho and Jobim (2014), the silage feed-out is made with a fork in 62% of the central-eastern region of Paraná State.

Only 10% of the producers did not discard silage, regardless of its state, and 42.5% discarded between 5 and 10 cm of the material, representing the majority of farms. The same pattern of discard regarding quantity was presented for all groups, yet group 3 was the only one in which 100% of farms discarded some portion of the material. In Brazil, only 11.2% of the producers discard deteriorated silage (Bernardes and Do Rêgo, 2014).

Regarding the silo panel management (Table 2), variation within and between the farm groups was observed. Only in group 4 did all producers withdraw slices larger than 20 cm. As for the total average, 27.5% withdrew slices smaller than 20 cm; 17.5% slices between 20 and 30 cm; and 35% and 20% slices measuring between 30 and 40 cm and larger than 40 cm, respectively.

As for monitoring and quality control of the silage, 45% of the farms assessed silo composition. Within the groups, the highest values were 50% for groups 2 and 4. The evaluation of dry matter (DM) was carried out by 43% of the producers, wherein 30% evaluated only at opening, 7.5% weekly, and 5% monthly. Group 4 represented the lowest percentage among those who evaluated the silo, where only 25% made this kind of monitoring, which is the same percentage as that for farms receiving technical assistance. It was found that 55% of farms received some kind of technical assistance, and the highest values were found in group 2, with 75% (Table 2).

Among the interviewees, 37% said that good-quality silage production was not influenced by any limitation (Table 2). However, within the limiting parameters, labor, weather, and available machines were highlighted, comprising 25%, 15%, and 12.5%, respectively. The same aspects were identified as the most concerning in the whole country (Bernardes, 2012). The farms in group 3 showed lower labor availability as the main factor (50%), while both groups 1 and 2 showed weather as the main factor with the same percentage (25%). In these two groups, other limitations highlighted were available machines (12.5% and 25%) and labor (18.8% and 12.5%) for groups 1 and 2, respectively. All the farms representing group 4 showed no limitations to production of good-quality silage.

Based on the categorical indicators and considering the data expressed in Tables 1 and 2, the groups can be described as follows (Figure 1): Group 1 represents the farms located in areas where environmental characteristics favored the corn growth, according to high silage quality, along with the usage of a suitable corn hybrid for silage production, and more efficient management practices applied in the crops. However, the investment in ensilage/silo feed-out processes was not as expressive as in groups 2 and 4, in which 50% of the farms in group 1 did not use any kind of additive or inoculant.

Group 2, as in Group 1, comprised the farms most benefited by local environmental characteristics in the season of corn crops used in silage production, in addition to the best corn hybrid usage and good management practices in crop growing. However, groups 1 and 3 stood out for the higher investment in the silage production process itself, with 100% of the bunker type silos associated with the use of black-on-white plastic film and inoculant addition, in addition to presenting the lowest percentage of properties that do not evaluate the composition of the silage and the highest amount of technical assistance (75%).

The farms represented by group 3 were characterized by being located where environmental conditions do not favor crop growing; not using the recommended corn hybrid; and not adopting good management practices — direct seeding was responsible for 91.7%, and it used only chemical fertilizer. Furthermore, they were the farms that least invested in ensilage/silo feed-out processes, with a higher percentage of farms that used a tractor-pulled ensilage machine and the stack silo type. Group 4, in turn, represented the farms located in areas where the crops were most affected by local environmental conditions, without proper corn hybrid usage, and with lower adoption of management practices in production. However, group 4 had the best investment regarding ensilage/silo feed-out processes, in which 100% of the silage production is outsourced, stored in a bunker silo with inoculants, and was covered with black-on-white plastic film.

No significant differences were observed (P>0.05) for any parameters within the formed groups, which was evident, as these indicators were not used as classificatory data. However, the largest farms were allocated to group 4, while those with higher cattle population were disposed in groups 1 and 2, and so the largest available area per animal (2.4 ha/animal) was in group 4 and the smallest was in group 1 (0.28 ha/animal). In this manner, silos with larger dimensions, and thus higher silage storage capacity, were grouped in group 1.

There were no differences (P>0.05) within the groups when the density of the ensiled matter was assessed, with an overall mean of 773.24 kg/m^3, demonstrating the caution given by producers for this crucial factor in the fermentation process. Density is determined by packing and is responsible, along with the DM content, for silage porosity, which has a determinant role in aeration and, consequently, in deterioration processes during ensilage and silo feed-out. Velho et al. (2007) observed better soluble sugar conservation, less carbohydrate structural change, and lower proteolysis in silage in second corn crop with the increase in packing from 500 kg/m^3 to 600 kg/m^3, ensuring better nutritional quality.

The average particle size (APS) was different (P<0.05) between the groups, due to the lower dimensions of particles (<19≥8 mm and <8 mm). Higher values were shown by group 1 (P<0.05) for particle size <8 mm than group 4, with 422.25 and 203.5 g/kg, respectively; however, neither group was different compared with groups 2 and 3. Higher quantities of particles sizes <19≥8 mm were found in group 4, and were different (P<0.005) compared with group 1. In this way, lower APS values were observed in the farms of group 1, with a significant difference (P<0.005) compared with group 3, which showed intermediate values for all particle sizes (19.67, 46.00, 589.08, and 345.25 g/kg for sizes ≥38, <38≥19, <19≥8, and <8 mm, respectively), thus resulting in higher APS values. Groups 1 and 3 did not differ with respect to APS values compared with groups 2 and 4.

According to Velho et al. (2007), because the most part of the national ensilage machines are not equipped to perform the plant crushing process after grinding, the two possible main factors that could influence silage packing are crop maturity and particle size.

No differences were observed (P>0.05) between values of total grain, whole grains, and broken grain in the ensiled matter, and there was no difference between superior, medium, and basal silo layer temperatures for the different groups of farms.

The temperature values are often used as a parameter for aerobic spoilage in silage, along with fungi formation in the peripheral areas of silos. The increase in silage temperature indicates oxidation of soluble carbohydrates,

Table 4 - Characterization of farm profile for each group (mean and standard deviation)

Indicator	Group				Overall mean	P>
	1	2	3	4		
Farm area (ha)	121.06 (±203.93)	328.78 (±304.44)	112.09 (±136.17)	841.50 (±1,444.62)	229.99 (±521.69)	0.068
Total number of animals	423 (±617)	445 (±374)	201 (±257)	350 (±285)	348 (±446)	0.585
Number of dairy cows	170 (±203)	222 (±234)	95 (±139)	207 (±215)	160 (±191)	0.504
Number of dry cows	27 (±32)	43 (±34)	15 (±13)	21 (±10)	25 (±26)	0.217
Number of silos	2.44 (±1.03)	3.50 (±2.67)	2.83 (±1.11)	2.50 (±0.58)	2.78 (±1.49)	0.427
Silage average yield (t ha^{-1})	57.17 (±26.76)	60.07 (±32.80)	40.08 (±11.69)	35.00 (±7.07)	49.17 (±23.41)	0.180
Silo size (m^3)	1,790.12 (±3,255.19)	1,080.34 (±1,146.76)	591.69 (±889.41)	1,567.47 (±2,251.65)	1,267.47 (±2,279.10)	0.584
Silage/silo quantity (t)	1,662.24 (±3,094.86)	1,022.01 (±1,324.43)	463.83 (±828.67)	1,147.05 (±1,506.31)	1,123.16 (±2,149.91)	0.558

lactic acid, and acetic acid, resulting in carbon dioxide and water production, with a consequent increase in temperature and pH (McDonald et al., 1991).

For temperature values, no differences were observed (P>0.05) for pH, and the farms' overall average pH value was 3.98. According to McDonald et al. (1991), in order to promote an efficient conservation of ensiled matter, the optimum pH range is between 3.6 and 4.5, which reveals that the silages had adequate fermentation.

Values of DM, MM, and CP did not differ between silages of different farm groups, averaging 330.07, 50.96, and 81.93 g/kg DM (Table 5). Silages with values lower than 300 g/kg DM may have high effluent production and *Clostridium* bacteria fermentation, resulting in an appreciable loss of soluble compounds, such as soluble nitrogen, sugar, fermentation products, and minerals (Fahey et al., 1994). If not treated properly, effluent losses lead to significant reductions of indigestible nutrients, as well as represent a potential hazard to the environment (Muck and Shinners, 2001).

Although there was no difference (P>0.05) between the MM levels for the different groups, lower overall values in groups 2 and 4 were found; these groups presented higher investment in silage/silo feed-out process across all farms utilizing corn crop-specific inoculant. Lower ash content suggests the occurrence of better forage preservation, as an improvement in the relative participation of MM on DM results from the loss of OM through inadequate fermentation processes (Silva et al., 2014).

Crude protein values were within the appropriate conditions for corn silage with good quality, which is considered to be 75-86 g/kg DM (Von Pinho et al., 2007). A lower concentration (P<0.05) of aflatoxins was observed in silages from groups 3 and 4, possibly due to less use of organic fertilizer (Table 1) concerning groups 1 and 2, as well as the better environmental conditions (location) during the season of corn crop growing (Figure 1). According to Zain (2011), the factors that contribute to the presence and production of mycotoxins in food and feed include environmental conditions, and storage and ecological conditions. Among the environmental factors that favor the occurrence of *Aspergillus flavus* are high air or soil temperature, water stress, nitrogen stress, agglomeration of plants, and conditions that help spreading of conidium during the crop silking (Adegoke and Letuma, 2013). As for storage conditions, Guerino et al. (2013) observed that moisture and fungi levels are the most important factors to consider.

According to Adegoke and Letuma (2013), to adopt mechanisms to control mycotoxins, it is essential to have

Table 5 - Physical and chemical characteristics of silage on different groups in southern farms of Brazil (mean and standard deviation)

Indicator	Group				Overall mean	P>
	1	2	3	4		
			Physical characteristics			
Density (kg m^{-3})	770.41 (±218.44)	865.45 (±165.46)	705.49 (±154.16)	803.40 (±160.10)	773.24 (±187.60)	0.316
Average particle size (mm)	11.33b (±1.21)	11.97ab (±1.62)	13.35a (±1.91)	13.34ab (±0.80)	12.27 (±1.72)	0.006
Particles ≥38 mm (g kg^{-1})	8.75 (±7.33)	10.00 (±8.28)	19.67 (±15.20)	8.00 (±13.47)	12.20 (±11.70)	0.063
Particles <38≥19 mm (g kg^{-1})	21.63 (±23.86)	38.00 (±48.62)	46.00 (±26.45)	66.00 (±37.88)	36.65 (±34.04)	0.065
Particles <19≥8 mm (g kg^{-1})	547.38b (±94.70)	606.25ab (±110.55)	589.08ab (±118.70)	722.50a (±91.29)	589.18 (±113.39)	0.041
Particles <8 mm (g kg^{-1})	422.25a (±93.64)	345.75ab (±131.76)	345.25ab (±108.14)	203.50b (±77.57)	361.98 (±120.23)	0.006
Silage total grains (g kg^{-1})	64.00 (±43.25)	83.50 (±35.23)	75.67 (±47.68)	66.00 (±57.46)	71.60 (±43.57)	0.755
Whole grains/total grains (g kg^{-1})	175.17 (±204.70)	138.74 (±206.10)	127.09 (±113.48)	41.73 (±54.37)	140.12 (±170.73)	0.574
Broken grains/total grains (g kg^{-1})	824.83 (±204.70)	861.26 (±206.10)	872.91 (±113.48)	958.28 (±54.37)	859.89 (±170.73)	0.574
Room temperature (ºC)	20.19 (±4.18)	22.66 (±5.05)	23.18 (±4.14)	23.25 (±3.97)	21.89 (±4.40)	0.264
Silo upper layer temperature (ºC)	27.81 (±4.47)	25.96 (±3.02)	28.24 (±6.92)	28.30 (±8.55)	27.62 (±5.40)	0.815
Silo middle layer temperature (ºC)	27.14 (±4.34)	26.84 (±2.56)	27.47 (±5.97)	25.10 (±2.66)	26.98 (±4.41)	0.836
Silo basal layer temperature (ºC)	27.43 (±3.68)	28.03 (±2.21)	26.77 (±4.86)	24.23 (±1.32)	27.03 (±3.74)	0.394
			Chemical characteristics			
pH	4.02 (±0.20)	3.76 (±0.11)	4.08 (±0.49)	3.95 (±0.25)	3.98 (±0.32)	0.173
Dry matter (g kg^{-1})	326.72 (±60.71)	328.43 (±28.24)	344.23 (±54.84)	304.30 (±69.45)	330.07 (±53.99)	0.630
Mineral matter (g kg^{-1} of DM)	57.28 (±37.12)	39.95 (±10.01)	54.41 (±32.02)	37.34 (±6.00)	50.96 (±30.07)	0.444
Crud protein (g kg^{-1} of DM)	81.63 (±11.44)	75.44 (±9.54)	83.56 (±7.75)	91.25 (±12.94)	81.93 (±10.72)	0.095
Aflatoxin (ppb)	12.46a (±1.08)	11.85a (±2.30)	8.46b (±2.30)	7.70b (±0.94)	10.66 (±2.64)	<0.0001
Zearalenone (ppb)	80.63 (±108.60)	43.49 (±44.70)	58.53 (±135.61)	18.88 (±24.15)	60.40 (±102.62)	0.699
Alcohol (g kg^{-1} of DM)	10.12 (±5.70)	8.96 (±5.74)	8.24 (±4.18)	5.97 (±3.82)	8.86 (±5.08)	0.5267
Acetic acid (g kg^{-1} of DM)	25.23 (±8.97)	22.02 (±8.76)	15.77 (±5.57)	28.66 (±14.59)	22.09 (±9.55)	0.0337
Propionic acid (g kg^{-1} of DM)	3.20ab (±1.98)	3.83ab (±3.38)	2.57b (±1.95)	7.95a (±7.26)	3.67 (±3.40)	0.0436
Butyric acid (g kg^{-1} of DM)	0.55 (±1.48)	0.20 (±0.21)	0.10 (±0.11)	0.09 (±0.04)	0.29 (±0.92)	0.6221
Lactic acid (g kg^{-1} of DM)	24.59 (±6.94)	22.05 (±5.03)	29.71 (±9.97)	29.10 (±8.92)	26.05 (±8.13)	0.1573

Means in the same row followed by different letters are different by Tukey's test (P<0.05).

relevant information about prevailing climatic conditions in agricultural areas where the crops are produced.

Another important factor regarding the occurrence of aflatoxin in crops is the use of glyphosate herbicide, which is commonly used for controlling undesired plants in soybean crops and is currently used in corn production, mainly with the advent of recently approved (CTNBIO, 2013) Roundup Ready® technology. Glyphosate favors the growth of *Aspergillus flavus* and *A. parasiticus* strains (Barberis et al., 2013).

Even with the highest aflatoxin concentrations, 12.46 and 11.85 ppb in groups 1 and 2, respectively (Table 5), the values are below the maximum levels allowed by Anvisa (Brazilian Health Surveillance Agency; RDC no. 7/2011 resolution), which sets the maximum level as 20 ppb for unprocessed or processed corn (Brasil, 2011). Fifty parts per billion is currently adopted as the maximum level for products destined for animal feed, as reported in Ordinance no. 7/1988, which was repealed by Normative Instruction no. 30/2009, without any new recommended values (Brasil, 1988; Brasil, 2009). According to Aragon et al. (2011), aflatoxin contents in corn forage are generally below the recommended limits and do not represent an issue.

As for aflatoxins, the average levels of zearalenone by farm groups were also below the maximum concentration stated by Anvisa (RDC no. 7/2011 resolution) (Brasil, 2011), which sets maximum levels of 400 ppb for corn and wheat for further processing (in force since January 2014). For products used in animal feed, Brazilian laws have not set maximum accepted limits, but according to Novisnki (2013), it can adopt levels of 285 ppb for corn silages.

The highest zearalenone concentrations were observed in farms of group 1 (80.63 ppb) and the lowest concentrations in group 4 (18.88 ppb), but not significantly different ($P>0.05$) between groups. Nevertheless, there was a wide variation among the visited farms, with values of 0.00 ppb (absence of mycotoxin) to 486.30 ppb for 27.5% and 2.5% of farms, respectively. However, 7.5% of silages presented levels above the allowed limit, available in groups 1 and 3, demonstrating that the presence of zearalenone is more closely related to regional and climatic factors, as well as the processes of crop growing, so ensilage/silo feed-out processes exert less influence on zearalenone levels.

Regarding propionic acid (Table 5), there were higher levels in silages of group 4 (7.95 g/kg DM), which was significantly higher ($P<0.05$) than group 3 (2.57 g/kg DM). This highlights the effect of investments in ensiling processes on the concentration of this acid, mainly the effect of inoculants, since both groups presented similar characteristics to the pre-silage phase. However, all forages of group 4 used inoculants composed of *Lactobacillus plantarum* and *Propionibacterium acidipropionici*. The latter group of bacteria produces a high concentration of propionic acid (Cummins and Johnson, 1992; Dawson et al., 1998). Undissociated propionic acid (COOH) presents fungicidal and fungistatic properties, acting to reduce and prevent the growth of yeasts and fungi at the time of silo opening, thus improving aerobic stability in the silage (Kung Jr. et al., 2003; Filya et al., 2004).

The silages of farm group 4 presented even, as a favorable factor to propionic acid production, longer fermentation/stabilization period of the ensiled material (silages opened after 3 months of ensiling or later). According to the results obtained by Filya et al. (2004), the propionic acid levels in silages of different crops is proportional to the number of days after ensiling.

Groups 1 and 2 presented intermediate concentrations of propionic acid, and were not different from the other farm groups.

Despite the higher average levels of acetic acid concentration in silages of group 4 (28.66 g/kg DM) and the lower levels in group 3 (15.77 g/kg DM), as indicative of inoculant usage and *P. acidipropionici* bacteria action on silages of group 4, there was no difference ($P>0.05$) between the different farm groups, expressing the higher capacity of *P. acidipropionici* to produce propionic acid instead to acetic acid. Rowghani et al. (2008) evaluated different doses of inoculants containing *L. plantarum* and *P. acidipropionici* on corn silage in laboratory silos and observed lower levels of propionic and acetic acid than those observed in the present research, which used the manufacturer's recommended dose.

No differences were observed between the groups regarding alcohol, lactic acid, and butyric acid contents, obtaining average values of 8.86, 26.05, and 0.29 g/kg DM, respectively (Table 5). Rowghani et al. (2008) observed, in inoculated corn silage, butyric and lactic acid values of 30.5 and 2.85 g/kg DM, respectively, whereas Filya et al. (2004) found no butyric acid in silages treated with *L. plantarum* and *P. acidipropionici*, which presented concentrations of 1.2 g/kg DM alcohol and 66.0 g/kg DM lactic acid. According to Santos et al. (2010), the butyric acid content reflects the extension of clostridia activity and is related to final higher pH levels. Concentrations below 3 g/kg DM indicate lower energy and dry matter losses (Tomich et al., 2003).

According to Ferreira (2001), silages with proper fermentation must show lactic acid levels of 60-80 g/kg DM, acetic acid <20 g/kg DM, propionic acid of 0-10 g/kg DM, butyric acid <1 g/kg DM, pH between 3.8 and 4.2, and $N-NH_3$ lower than 100 g/kg of the total nitrogen. Based on the evaluated criteria, it was observed that the silages showed low concentrations of lactic acid (26.05 g/kg DM) and values slightly above the limit for acetic acid (22.09 g/kg DM), keeping the other fermentative parameters within the optimal limit, generally indicating the good production efficiency and silage quality produced on farms evaluated in Southern Brazil, even among small-and medium-sized producers.

Conclusions

Dairy farms evaluated in Southern Brazil, regardless of their size, invest in different stages of silage production processes, generally being characterized as high-technology farms.

Technical indicators characterizing the differences among the farms are related to location/weather, crop management, corn quality, and investment on silage/silo feed-out process. The technologies used in silage production are more closely associated with the crop implementation and crop growing processes, which is more evident among the farms situated in the state of Paraná.

The farms in Rio Grande do Sul State distinguish themselves as to investment in ensilage and silo feed-out processes mainly by their high adhesion of outsourcing services, self-propelled machinery usage, bunker silos, black-on-white plastic film, and specific inoculant for the aerobic deterioration control.

References

Adegoke, G. O. and Letuma, P. 2013. Strategies for the prevention and reduction of mycotoxins in developing countries. p.123-136. In: Mycotoxin and food safety in developing countries. 1st ed. InTech, Croatia.

Aragon, Y. A.; Rodrigues, I.; Hofstette, U. and Binder, E. M. 2011. Mycotoxins in silages: Occurrence and prevention. Iranian Journal of Applied Animal Science 1:1-10.

Barberis, C. L.; Carranza, C. S.; Chiacchiera, S. M. and Magnoli, C. E. 2013. Influence of herbicide glyphosate on growth and aflatoxin B_1 production by *Aspergillus* section *Flavi* strains isolated from soil on *in vitro* assay. Journal of Environmental Science and Health, Part B: Pesticides, Food Contaminants, and Agricultural Wastes 48:1070-1079.

Bernardes, T. F. 2012. Levantamento das práticas de produção e uso de silagens em fazendas leiteiras no Brasil. Universidade Federal de Lavras, Lavras (E-book).

Bernardes, T. F.; Carvalho, I. Q. and Silva, N. C. A. 2012. Snapshot of maize silage quality on dairy farms in South Brazil. p.322-323. In: Proceedings of International Silage Conference. University of Helsinki, Finland.

Bernardes, T. F. and Do Rêgo, A. C. 2014. Study on the practices of silage production and utilization on Brazilian dairy farms. Journal of Dairy Science 97:1852-1861.

Borreani, G. and Tabacco, E. 2010. The relationship of silage temperature with the microbiological status of the face of corn silage bunkers. Journal of Dairy Science 93:2620-2629.

Brasil. Agência Nacional de Vigilância Sanitária. 2011. Resolução RDC nº 7 de 18 de fevereiro de 2011: Dispõe sobre limites máximos tolerados (LMT) para micotoxinas em alimentos. Diário Oficial da União, Seção I, n.46, p.66-67.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. 1988. Portaria nº 7 de 09 de novembro de 1988: Baixa os padrões mínimos de matéria prima destinada à alimentação animal. Diário Oficial da União, Seção I, s/n, p.21968-21974.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. 2009. Instrução Normativa nº 30 de 5 de agosto de 2009: Estabelece critérios e procedimentos para o registro de produtos, para rotulagem e propaganda e para isenção da obrigatoriedade de registro de produtos destinados à alimentação de animais de companhia. Diário Oficial da União, Seção I, n.150, p.13-16.

Carvalho, I. Q. and Jobim, C. C. 2014. Impacto da tecnologia de ensilagem no valor nutricional da silagem e na resposta animal. p.265-285. In: Anais do 5º Simpósio Produção e Utilização de Forragens Conservadas. Universidade Estadual de Maringá, Maringá.

CTNBIO – Comissão Técnica Nacional de Biossegurança. 2011. Parecer técnico nº 3045/2011. Available at: <http://www.ctnbio.gov.br/index.php/content/view/ 16683.html> Accessed on: Nov, 21, 2013.

Cummins, C. S. and Johnson, J. L. 1992. The genus *Propionibacterium*. p.834-849. In: The prokaryotes. 2nd ed. Springer-Verlag, New York.

Dawson, T. E.; Rust, R. S. and Yokoyama, M. T. 1998. Improved fermentation and aerobic stability of ensiled, high moisture corn with the use of *Propionibacterium acidipropionici*. Journal of Dairy Science 81:1015-1021.

Fahey G. C. J.; Collins, M.; Mertens, D. R. and Moser, L. E. 1994. Forage quality, evaluation, and utilization. American Society of Agronomy, Madison, WI.

Ferreira, J. J. 2001. Estágio de maturação ideal para ensilagem do milho e do sorgo. p.405-428. In: Produção e utilização de silagem de milho e sorgo. 1.ed. Embrapa Milho e Sorgo, Sete Lagoas.

Filya, I.; Sucu, E. and Karabulut, A. 2004. The effect of *Propionibacterium acidipropionici*, with or without *Lactobacillus plantarum*, on the fermentation and aerobic stability of wheat, sorghum and maize silages. Journal Applied Microbiology 97:818-826.

Guerino, D.; Scheufele, F. B.; Hasan, S. D. M. and Fiorese, M. L. 2013. Condições de armazenamento das sojas orgânicas e convencional sobre suas qualidades químicas e microbiológica. Revista Brasileira de Produtos Agroindustriais 15:69-79.

Jobim, C. C.; Nussio, L. G.; Reis, R. A. and Schmidt, P. 2007. Avanços metodológicos na avaliação da qualidade de forragem conservada. Revista Brasileira de Zootecnia 36:101-119.

Jobim, C. C. and Nussio, L. G. 2014. Princípios básicos da fermentação na ensilagem. p.649-670. In: Forragicultura: Ciência, tecnologia e gestão dos recursos forrageiros. 1.ed. Jaboticabal, FUNEP.

Kung Junior, L.; Grieve, D. B.; Thomas, J. W. and Huber, J. T. 1984. Added ammonia or microbial inocula for fermentation and nitrogenous compounds of alfafa ensiled at various percents of dry matter. Journal of Dairy Science 67:299-306.

Kung Junior, L.; Stokes, M. R. and Lin, C. J. 2003. Silage additives. p.305-360. In: Silage science and technology. 1st ed. American Society of Agronomy, Madison, WI.

Mari, L. J. and Nussio, L. G. 2002. O método Penn State Particle Size Separator para a predição do tamanho de partículas de silagens. Available at: <http://www.beefpoint.com.br/bn/radarestecnicos> Accessed on: Jun, 15, 2012.

McDonald, P.; Henderson, N. and Heron, S. 1991. The biochemistry of silage. 2nd ed. Marlow, Chalcombe.

Muck, R. E. and Shinners, K. J. 2001. Conserved forage (silage and hay): progress and priorities. p.753. In: Proceedings of the 19º International Grassland Congress. Brazilian Society of Animal Husbandry, São Pedro.

Novaes, L. P.; Lopes, F. C. F. and Carneiro, J. C. 2004. Silagens: oportunidades e pontos críticos. 1.ed. Embrapa Gado de Leite, Juiz de Fora.

Novisnki, C. O. 2013. Composição de micotoxinas e bromatologia de silagens de milho em silosde grande porte utilizando imagens em infravermelho. Dissertação (M.Sc.). Universidade Federal do Paraná, Curitiba.

Pereira, J. R. A. 2011. Custom services for forage conservation services. p.183-195. In: Proceedings of the 2nd International Symposium on Forage Quality and Conservation. ESALQ/USP, São Pedro.

Rowghani, E.; Zamiri, M. J.; Khorvash, M. and Abdollahipanah, A. 2008. The effects of *Lactobacillus plantarum* and *Propionibacterium acidipropionici* on corn silage fermentation, ruminal degradability and nutrient digestibility in sheep. Iranian Journal of Veterinary Research 9:308-315.

Santos, R. D.; Pereira, L. G. R.; Neves, A. L. A.; Araújo, G. G. L.; Voltolini, T. V.; Brandão, L. G. N.; Aragão, A. S. L. and Dórea, J. R. R. 2010. Características de fermentação da silagem de seis variedades de milho indicadas para a região semiárida brasileira. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 62:1423-1429.

Sassahara, M.; Yanaka, E. K. and Pontes Netto, D. 2003. Ocorrência de aflatoxina e zearalenona em alimentos destinados ao gado leiteiro na Região Norte do Estado do Paraná. Semina: Ciências Agrárias 24:63-72.

Satter, L. D. and Reis, R. B. 2012. Milk production under confinament conditions. Available at: <http://www.ars.usda.gov/research/publications/publications.htm? seq_no_115=84465> Accessed on: Sept 3, 2012.

Shanta, N. C. and Napolitano, G. E. 1992. Gas chromatography of fatty acids. Journal of Chromatography 624:37-51.

Silva, D. J. and Queiroz, A .C. 2002. Análise de alimentos: Métodos químicos e biológicos. 3.ed. Universidade Federal de Viçosa, Viçosa, MG.

Silva, M. S. J.; Jobim, C. C.; Nascimento, W. G.; Ferreira, G. D. G. and Oliveira, M. R. 2014. Uso de aditivos e tempo de abertura dos silos em silagens de estilosantes campo grande. Revista Brasileira de Saúde e Produção Animal 15:381-393.

Tomich, T. R.; Pereira, L. G. R.; Gonçalves, L. C.; Tomich, R. G. P. and Borges, I. 2003. Características químicas para avaliação do processo fermentativo de silagens: uma proposta para qualificação da fermentação. 1st ed. Embrapa Pantanal, Corumbá, MS.

Velho, J. P.; Mühlbach, P. R. F.; Nörnberg, J. L. Velho, I. M. P. H.; Genro, T. C. M. and Kessler, J. D. 2007. Composição bromatológica de silagens de milho produzidas com diferentes densidades de compactação. Revista Brasileira de Zootecnia 36:1532-1538.

Von Pinho, R. G.; Vasconcelos, R. C.; Borges, I. D. and Resende, A. V. 2007. Produtividade e qualidade da silagem de milho e sorgo em função da época de semeadura. Bragantia 66:235-245.

Ward, J. H. 1963. Hierarchical grouping to otimize an objective function. Journal American Association 58:236-244.

Zain, M. E. 2011. Impact of mycotoxins on humans and animals. Journal of Saudi Chemical Society 15:129-144.