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Nutritive value of corn silage from intensive dairy farms in Brazil

Isabella Lasmar de Oliveira[1], Luciana Miranda Lima[1], Daniel Rume Casagrande[1], Márcio André Stefanelli Lara[1], Thiago Fernandes Bernardes[1*]

[1] *Universidade Federal de Lavras, Departamento de Zootecnia, Lavras, MG, Brazil.*

ABSTRACT - The objective of this research was to characterize the nutritive value of corn silage made on intensive dairy farms and demonstrate the nutritional variations between silages located at the top and at the center of a bunker silo. Thirty-two dairy farms were visited in four Brazilian states. One corn bunker silo of each farm was chosen and samples were collected from the top and center parts. The nutritive value, fermentation end-products, and microbial counts were assessed. The predicted milk was determined by Milk2006 spreadsheet. The mean, standard deviation, maximum, minimum, and 95% confidence interval of all data were calculated. The ash, neutral detergent fiber (NDF), starch, *in vitro* NDF, and dry matter (DM) digestibility data were compared with reference value. Both statistical procedures were performed through the PROC MEANS of SAS. The mean values found at the center for NDF, starch, total digestible nutrients (TDN_{-1x}), and estimated milk were 503 g kg^{-1} DM, 308 g kg^{-1} DM, 583 g kg^{-1}, and 1,124 kg t^{-1}, respectively. The top silages presented a mean TDN_{-1x} and predicted milk of 559 g kg^{-1} and 1046 kg t^{-1}, respectively. For NDF digestibility and starch concentration, 53.1% and 62.5% of the center samples presented a value equal to or above the reference value (500 g kg^{-1} and 300 g kg^{-1} DM for NDF digestibility and starch concentration, respectively). Overall, the corn silage produced on intensive dairy farms in Brazil has satisfactory nutritive value, especially in terms of starch concentration. Some parameters, such as the concentration of fiber and its digestibility, should be improved. This study also shows that a silo may contain two different types of silage: top and center. This alerts nutritionists and farmers when feeding and sampling corn silage from bunker silos.

Key Words: aerobic deterioration, feed composition, feed sampling, maize silage

Introduction

Milk production in Brazil originates mainly from small farms with low investment in technologies. However, in recent years, the number of dairy farms with a specialized herd and high daily volume of milk (above 5,000 L/day) has increased. These features establish Brazil as the fourth largest milk producer in the world (USDA, 2015).

Corn silage is the main source of forage used in the diet of Brazilian high-producing dairy cows (Bernardes and Do Rêgo, 2014). High-quality corn silage contributes energy and fiber to dairy cattle (Ferraretto et al., 2015). However, the variations that occur in the chemical composition of silage, as well as changes in fermentation characteristics, can influence intake and milk production (Oba and Allen, 1999; Huhtanen et al., 2003; Huhtanen et al., 2007; Khan et al., 2015).

In countries where the dairy industry is well established, the standards for corn silage production, as well as the nutritive value of silage, are already well described in the literature (Ferraretto and Shaver, 2013; Khan et al., 2015; Gallo et al., 2016). Conversely, in hot environments, such as in Brazil, the quality of corn silage is influenced by production techniques (e.g., less resource availability), type of hybrid (e.g., predominance of flint corn), and climatic factors (e.g., proliferation of many pests and bacterial and fungal pathogens; Adesogan, 2009; Adesogan, 2010). Furthermore, to our best knowledge, no articles exist in the literature on the nutritive value of corn silage produced in Brazil at a commercial scale. Besides, when considering commercial bunker silos in Brazil, our research team has noticed that some aspects of the corn silage (e.g., color, smell, and presence of molds) have varied greatly between the upper layer (top) and the central part of the silo as a function of aerobic deterioration (Da Silva et al., 2014; Lima et al., 2017). Thus, we hypothesized that the availability of nutritional data could show which parameters need to be improved as well as help nutritionists and producers with the formulation of diets when corn silage is used as a forage source. Hence, the objective of this study was to characterize

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***Corresponding author:** thiagobernardes@dzo.ufla.br

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the nutritive value of corn silage from intensive dairy farms in Brazil. In addition, because the aerobic deterioration of silage is more intense under warm conditions and at the top of the bunker, a secondary objective was to demonstrate the nutritional variations that can occur between silages at the center and at the top of the silos.

Material and Methods

Thirty-two dairy farms in the states of Minas Gerais (n = 24), São Paulo (n = 2), Paraná (n = 4), and Rio Grande do Sul (n = 2) were visited. Those farms were chosen to represent an intensive dairy farming system. The daily milk production ranged from 1,500 to 48,000 L/day and the mean production per animal was 28.4 L/cow/day. The cows were raised in feedlot (81%) or semi-confinement (19%). The samples were collected between the months of August and November 2012 (n = 12) and between February and August 2014 (n = 20). The maximum, minimum, and mean ambient temperature on the sampling day ranged between 23-32 °C, 9.2-20 °C, and 17.3-25.8 °C, respectively.

On each farm, one bunker silo was assessed and the following parameters were determined: height, width, and length of the silo, silage density, silage particle size, and feed-out rate (Table 1). For the analysis of density, six samples were collected. The first was collected at 0.30 m from the top and at mid-width (center top). Another sample was taken from each side, 0.30 m from the top and 0.30 m from the side. The other samples were collected at 1.5 m from the bottom of the silo and 0.30 m from each wall or mid-width. Samplings were taken using a probe with a 46-mm diameter and 227-mm length attached to a portable drill (Muck and Holmes, 2000). Then, the samples were weighed; each sample weight was related to the probe volume for the calculation of the density. The average size of particles was determined through the method described by Heinrichs and Kononoff (2002).

Table 1 - Silage particle size and characteristics of the bunker silos used in the study

	Mean	Minimum	Maximum	SD
Mean particle size (mm)	12.7	9.30	18.3	2.74
Silo dimensions (m)				
Length	60.0	23.0	134	28.6
Width	9.66	4.15	35.5	6.47
Wall height	3.13	1.55	5.80	1.12
Wet density (kg m^{-3})				
Center	699	463	974	139
Top	540	298	884	149
Feed-out rate (m day^{-1})	0.67	0.19	1.53	0.33

SD - standard deviation.

The samples used for determining the chemical, fermentation, and microbial analyses were collected as follows: the first one was collected at mid-width and 0.40 m from the top, the second at 0.40 m from the top and 0.40 m from the wall, and the third sample was taken from the center of the silo. At those three locations, two samples were collected, 20 cm from each other. After the collections, all samples were immediately packed and vacuum-sealed.

The main characteristics of the silage making process were recorded via a questionnaire, which was answered by the producer at the time of the visit to the farms (Table 2).

The collected samples were subdivided into three subsamples. The first subsample was used for chemical analysis (two replicates). This sample was placed in a forced-air oven at 60 °C for 72 h for the determination of the dry matter (DM), according to the guidelines of the Association of Official Analytical Chemists (AOAC, 1990), and the sample was ground in a mill with 1-mm mesh sieve for later determination of ash (AOAC, 1990), crude protein (CP) (AOAC, 1990), and neutral detergent fiber (NDF) using thermostable α-amylase (Van Soest et al., 1991) and starch (Hall and Mertens, 2008). The non-fibrous carbohydrates (NFC) were calculated according to the equation proposed

Table 2 - Practices adopted for production and utilization of corn silages on intensive dairy farms in Brazil (n = 32)

Item	%
Additive	
Yes	62.5
No	37.5
Harvester	
Pull-type	46.9
Self-propelled	53.1
Silo	
Bunker	100
Cover wall with plastic film	
No	84.4
Yes	15.6
Plastic film	
Black	28.1
Black-on-white	59.4
Oxygen barrier film	12.5
Weight on the plastic film	
None	9.40
Grass	12.4
Tires	9.40
Soil	59.4
Bags with sand	9.40
Silage removal	
Manual	12.5
Defacer	87.5
Removal of the face	
50%	15.6
100%	84.4

by Sniffen et al. (1992), NFC = 100 − (CP + EE + Ash + NDF). The ether extract (EE) was considered constant and equal to 3.2% for all samples, according to the NRC (2001). The *in vitro* dry matter (IVDMD) and NDF (NDFD) digestibilities were determined by the method proposed by Holden (1999) using the DAISY II apparatus (ANKOM Technology Corp, Fairport, NY, USA). The ruminal fluid was collected via cannula, 2 h after the morning feed. Two Tabapuã heifers were given a diet containing 80% corn silage and 20% concentrate. Samples were digested for 48 h in quadruplicate. The total digestible nutrients at 1x maintenance (TDN_{-1x}), net energy for lactation at 3x maintenance (NE_{L-3x}), and predicted milk (kg t^{-1} DM) were estimated according to the MILK2006 spreadsheet (Shaver et al., 2006).

The second subsample was used to assess pH, ammonia nitrogen (NH_3-N), and volatile fatty acids (two replicates). The silage extract was obtained after homogenization in a Stomacher device (model 400 circulator, Seward Inc., Bohemia, New York, USA) for 4 min, using 30 g of fresh sample and 270 g of distilled water. The measurement of pH and NH_3-N was performed using a specific electrode coupled to a multiparameter meter (Orion Star A214 pH/ISE benchtop meter, Thermo Scientific, Waltham, MA, USA). For the determination of volatile fatty acids (lactic, acetic, propionic, and butyric acids), high-performance liquid chromatography was used (Shimadzu LC 10 Ai; Shimadzu Corp., Tokyo, Japan). A 2-mL aliquot was added to Eppendorf tubes containing 0.01 mL of 50% sulfuric acid for centrifugation, filtering, and injection. An ultraviolet radiation (UV-vis) detector was used at a wavelength of 210 nm. The device was equipped with an ion-exclusion column (SUPELCO-SUPELCOGEL 8H (5 cm × 4.8 mm)) operating at 30 °C with a flow rate of 0.6 mL/min and using water and 0.005 M sulfuric acid as the mobile phase.

The third subsample was used to count lactic acid bacteria (LAB), yeasts, and molds. An aqueous extract with 30 g of sample and 270 of peptone water was used and homogenized in a Stomacher as described above. The counts were made using the surface-plating technique with MRS agar culture medium (Himedia, Biosytems Comercial de Importação e Exportação e Equipamentos para Laboratório, Brazil) for LAB and yeast extract glucose chloramphenicol agar (YGC agar; Fluka, Sigma Aldrich Química, Brazil) for yeasts and molds (Tabacco et al., 2009); duplicate serial dilutions were prepared. The Petri dishes were incubated at 35 °C for three days for LAB and at 28 °C for three and five days for yeasts and molds, respectively. The colonies were then counted based on their macromorphological characteristics.

The microbial counts were log10-transformed to obtain normal distribution of the data. Initially, the mean, standard deviation, maximum, minimum, and 95% confidence interval of all data were calculated using the PROC MEANS procedure of SAS software (Statistical Analysis System, version 9.1). Then, a correlation analysis of the chemical composition, estimates of milk production, fermentation profile, and microbial count from the center and top of each silo was performed through Pearson's correlation at 5% probability, using the PROC CORR procedure of SAS. Finally, the ash, NDF, starch, IVDMD, and NDFD data of each silo were compared with reference values. The data were transformed by subtracting the reference value (constant) from the mean of each farm. When the result of the transformation was equal to zero, we considered the mean of that farm to be equal to the reference value. When nonzero, the mean of the farm was considered higher than the reference value if the result of the transformation was greater than zero and considered lower than the reference value if it was less than zero. This analysis was performed using Student's t-test, with a significance level of 5%, through the PROC MEANS procedure of SAS.

Results

The center silage samples had a mean of 351 g kg^{-1}, 503, and 308 g kg^{-1} DM for DM, NDF and starch concentrations, respectively (Table 3). These parameters showed a confidence interval of 334 to 369 g kg^{-1}, 484 to 523 g kg^{-1} DM, and 285 to 332 g kg^{-1} DM, respectively. The confidence interval for NDFD was 375 to 436 g kg^{-1} DM and the mean value was 407 g kg^{-1} DM. For the variables TDN_{-1x}, NE_{L-3x}, and milk production, the means were 583 g kg^{-1}, 1.31 Mcal kg^{-1} DM, and 1,124 kg t^{-1}, respectively. The top silage samples had a mean DM concentration of 344 g kg^{-1}. The confidence interval for NDF and starch were 509 to 540 g kg^{-1} DM and 271 to 311 g kg^{-1} DM, respectively. These variables had mean values of 524 and 291 g kg^{-1} DM, respectively. The NDFD mean value was 388 g kg^{-1} DM and had a confidence interval of 361 to 416 g kg^{-1} DM. The mean values of TDN_{-1x}, NE_{L-3x}, and milk production were 559 g kg^{-1}, 1.25 Mcal kg^{-1} DM, and 1046 kg t^{-1}, respectively.

The silage samples taken from the center of the silos had mean values of lactic acid and pH of 70.4 g kg^{-1} DM and 3.86, respectively (Table 4). The mean counts of yeasts and molds were 1.94 and 1.19 log cfu g^{-1}, respectively. The confidence intervals for these parameters were 1.36 to 2.53 log cfu g^{-1} and 1.00 to 1.42 log cfu g^{-1}, respectively. The silage samples from the top of the silos had a mean of 58.3 g kg^{-1} DM and a mean pH of 4.01. The confidence interval for the yeast count was 1.69 to 2.84 log cfu g^{-1} and the mean value was 2.26 log cfu g^{-1}. The mold count presented a mean value of 1.43 log cfu g^{-1} and a confidence interval of 1.17 to 1.68 log cfu g^{-1}.

For the ash concentration, 96.9% of the samples collected from the center and 87.5% of the samples from the top yielded a value for this parameter equal to the adopted reference (38 g kg^{-1} DM) (Table 5). For NDF, 31.2% of the silage samples from the center and 28.1% of those from the top were equal to or below the reference value adopted (450 g kg^{-1} DM). As for the starch concentration of the silages, 62.5% of the samples from the center and 68.8% of those from the top presented values equal to or greater than the reference value (300 g kg^{-1} DM). For NDFD, 53.1% of the center samples presented a value equal to or above the reference value (500 g kg^{-1} DM). As for the top samples, 37.5% of the samples had an NDFD equal to the reference adopted. For IVDMD, 62.5% of the samples from both positions in the silos had values equal to or above the reference value (680 g kg^{-1} DM).

The silage samples taken from the center of the silo presented no correlation (P>0.05) with the samples found at the top for the concentrations of the ash, lactic acid, butyric acid, pH, and mold count (Table 6).

Discussion

The chemical composition of corn silage is influenced by the type of hybrid, agronomic practices, plant growth and ensiling conditions, and the maturity stage of the plant at harvest (Johnson et al., 1999; Bal et al., 2000; Khan et al., 2012). With the advancing maturity of the corn crop, the grain content increases, raising the concentration of starch and reducing the NDF concentration (Johnson et al., 1999). Corn silage produced in warm climates tend to present greater concentrations of NDF and less starch in comparison with corn silage produced in temperate areas (Adesogan, 2010). The NDFD is also lower in plants grown in warm climate regions (Cone and Engels, 1990; Adesogan, 2010). In addition to the direct effects of climate conditions on

Table 3 - Chemical composition, energy estimates, and predicted milk of corn silage located at the center and top of bunker silos

Item	Center					Top				
	Mean	Minimum	Maximum	SD	Confidence interval	Mean	Minimum	Maximum	SD	Confidence interval
DM (g kg^{-1})	351	259	472	4.88	334-369	344	260	491	6.02	322-365
Ash (g kg^{-1} DM)	36.4	27.6	73.8	0.86	33.3-39.5	45.3	25.2	176	2.96	34.6-56.0
CP (g kg^{-1} DM)	76.2	61.3	97.3	0.87	73.1-79.4	78.3	54.4	100	0.99	74.8-81.9
NDF (g kg^{-1} DM)	503	404	642	5.30	484-523	524	440	632	4.33	509-540
NFC (g kg^{-1} DM)	350	205	463	5.54	330-370	318	209	420	5.36	298-337
Starch (g kg^{-1} DM)	308	163	418	6.41	285-332	291	155	380	5.44	271-311
NDFD (g kg^{-1} DM)	407	249	606	7.95	375-436	388	171	494	7.66	361-416
IVDMD (g kg^{-1} DM)	669	595	749	4.20	653-684	649	556	725	4.63	632-666
TDN_{-1x} (g kg^{-1})	583	489	700	5.05	565-602	559	466	648	5.13	541-578
NE_{L-3x} (Mcal kg^{-1} DM)	1.31	1.09	1.53	0.10	1.27-1.34	1.25	1.01	1.46	0.11	1.21-1.29
Milk (kg t^{-1} DM)	1124	828	1471	147	1071-1177	1046	723	1335	157	990-1103

DM - dry matter; CP - crude protein; NDF - neutral detergent fiber; NFC - non-fibrous carbohydrates; NDFD - *in vitro* neutral detergent fiber digestibility; IVDMD - *in vitro* dry matter digestibility; TDN_{-1x} - total digestible nutrients at 1x maintenance; NE_{L-3x} - net energy for lactation at 3x maintenance; SD - standard deviation.

Table 4 - Fermentative profile and microbial counts of corn silage located at the center and top of bunker silo

Item	Center					Top				
	Mean	Minimum	Maximum	SD	Confidence interval	Mean	Minimum	Maximum	SD	Confidence interval
NH_3-N (g kg^{-1} Total N)	109	31.2	227	4.25	94.0-125	94.3	46.0	174	3.34	82.3-106
Lactate (g kg^{-1} DM)	70.4	33.5	135	2.58	61.1-79.7	58.3	16.5	142	2.79	48.3-68.4
Acetate (g kg^{-1} DM)	13.0	2.00	22.2	0.55	11.0-14.9	11.8	3.50	21.8	0.53	9.92-13.7
Propionate (g kg^{-1} DM)	17.7	4.00	41.8	1.18	13.4-21.9	12.0	3.40	27.9	0.70	9.46-14.5
Butyrate (g kg^{-1} DM)	2.44	0.00	27.7	0.47	0.75-4.14	1.65	0.40	5.40	0.10	1.29-2.03
pH	3.86	3.59	4.13	0.13	3.81-3.91	4.01	3.65	4.80	0.29	3.90-4.11
LAB (log cfu g^{-1})	4.59	1.00	8.09	1.97	3.88-5.30	5.23	1.00	8.24	2.28	4.41-6.05
Yeasts (log cfu g^{-1})	1.94	1.00	6.43	1.61	1.36-2.53	2.26	1.00	5.90	1.60	1.69-2.84
Molds (log cfu g^{-1})	1.19	1.00	3.59	0.64	1.00-1.42	1.43	1.00	3.80	0.71	1.17-1.68

NH_3-N - ammonia nitrogen; LAB - lactic acid bacteria; cfu - colony-forming units; SD - standard deviation.

the growth of corn plants, the hot and humid conditions in the tropics also influence the ensiling process. The high temperatures during ensiling and unloading of the silo can increase the growth rate of the spoilage microorganisms, thereby intensifying the aerobic deterioration process (Ashbell et al., 2002).

Starch is the main source of energy in corn silage and it is a quantitatively important nutrient for the performance of high-producing dairy cows (Jensen et al., 2005). In addition to the silages produced in warm climate regions tending to present lower starch concentrations, corn grown in Brazil contains a high proportion of vitreous endosperm, which is inversely related to the starch digestibility (Lopes et al., 2009). Thus, the processing of the grain could be an alternative for increasing the availability of starch and optimizing the energy content of vitreous endosperm hybrids.

Most silages analyzed in this study presented a concentration of starch similar to or above 300 g kg^{-1} DM (Table 5). We did not assess the endosperm texture and the degree of grain processing (factors that affect the availability of starch to the animal), but the high concentration of starch stimulates the production of microbial protein in the rumen, increasing the production and concentration of milk protein (Ferraretto et al., 2013; Lascano et al., 2016).

Dairy cows also require forage fiber in their diet to maintain rumen function and maximize milk production; however, the excess NDF limits intake due to its contribution to rumen filling (Krämer-Schmid et al., 2016). Because intake is an important factor for milk production, not only the concentration of NDF, but also its digestibility is a determinant of the nutritive value of corn silage (Huhtanen et al., 2006). The reference value adopted in this study for NDF (450 g kg^{-1} DM) and NDFD (500 g kg^{-1} DM) are considered accurate, because these are usually found in silages of temperate climates. Even with the limitations of producing silages with high nutritive value in hot environments, some farms still had NDF and NDFD values similar to the reference adopted.

Bunker silos often enable aerobic deterioration of silage (Bolsen et al., 1993), especially at the top, because this area presents lower density compared with the central area of the silo (D'Amours and Savoie, 2005). Holmes (2009) recommended a bulk density greater than 705 kg m^{-3} and porosity less than 0.4 as ideal values for corn silage. In this study, the top region had lower density (on average 540 kg m^{-3}) than the central part (on average 699 kg m^{-3}), which led to the greater development of undesirable microorganisms such as yeasts and molds, which may have led to the aerobic deterioration of silage in the top area. Those microorganisms utilize fermentation products to growth, leading to nutritional and energy losses (Lindgren et al., 2002). The silages located at the top of the silo,

Table 5 - Distribution of samples of corn silage located at the center and top of bunker silos, considering the reference value for ash, NDF, starch, NDFD, and IVDMD

Item	Center		Top	
	n	%	n	%
Ash (g kg^{-1} DM)				
<38	0	0.00	0	0.00
38	31	96.9	28	87.5
>38	1	3.10	4	12.5
NDF (g kg^{-1} DM)				
<450	1	3.10	0	0.00
450	9	28.1	9	28.1
>450	22	68.8	23	71.9
Starch (g kg^{-1} DM)				
<300	12	37.5	10	31.2
300	6	18.8	16	50.0
>300	14	43.7	6	18.8
NDFD (g kg^{-1} DM)				
<500	15	46.9	20	62.5
500	16	50.0	12	37.5
>500	1	3.10	0	0.00
IVDMD (g kg^{-1} DM)				
<680	12	37.5	12	37.5
680	14	43.7	18	56.2
>680	6	18.8	2	6.30

NDF - neutral detergent fiber; NDFD - *in vitro* neutral detergent fiber digestibility; IVDMD - *in vitro* dry matter digestibility; DM - dry matter.

Table 6 - Correlation coefficient of the chemical composition, energy estimates, predicted milk, fermentation profile, and microbial counts of corn silage located at the center and top of bunker silos

Item	Correlation coefficient	P-value
DM (g kg^{-1})	0.795	<0.001
Ash (g kg^{-1} DM)	0.123	0.503
CP (g kg^{-1} DM)	0.525	0.002
NDF (g kg^{-1} DM)	0.767	<0.001
NFC (g kg^{-1} DM)	0.653	<0.001
Starch (g kg^{-1} DM)	0.795	<0.001
NDFD (g kg^{-1} DM)	0.623	0.001
IVDMD (g kg^{-1} DM)	0.779	<0.001
TDN_{-1x} (g kg^{-1})	0.466	0.007
NE_{L-3x} (Mcal kg^{-1} DM)	0.426	0.015
Milk (kg ton^{-1} DM)	0.429	0.014
NH_3-N (g kg^{-1} Total N)	0.738	<0.001
Lactate (g kg^{-1} DM)	0.166	0.365
Acetate (g kg^{-1} DM)	0.584	0.001
Propionate (g kg^{-1} DM)	0.572	0.001
Butyrate (g kg^{-1} DM)	−0.117	0.526
pH	0.024	0.896
LAB (log cfu g^{-1})	0.565	0.001
Yeasts (log cfu g^{-1})	0.623	0.001
Molds (log cfu g^{-1})	−0.187	0.306

DM - dry matter; CP - crude protein; NDF - neutral detergent fiber; NFC - non-fibrous carbohydrates; NDFD - *in vitro* neutral detergent fiber digestibility; IVDMD - *in vitro* dry matter digestibility; TDN_{-1x} - total digestible nutrients at 1x maintenance; NE_{L-3x} - net energy for lactation at 3x maintenance; NH_3-N -ammonia nitrogen; LAB - lactic acid bacteria; cfu - colony-forming units.

in addition to presenting reduced nutritive value, also had lower estimates for NE_{L-3x} and milk production. The management necessary to prevent aerobic deterioration at the top of bunkers requires proper chop length, good packing, coverage with plastic, and a proper feed-out rate. Among these alternatives, the quality of the plastic film and how well it is secured to the crop are considered keys to eliminating top spoilage, as reported by Lima et al. (2017). Those authors evaluated two covering systems in dairy farm bunker silos: an oxygen barrier film on the walls and top lateral compared with no wall film and a single layer of standard polyethylene film top cover. The shoulder silage under the oxygen barrier film was similar to that in the central core of the silo (positive control) and significantly better than the shoulder silage under the standard covering system, with greater milk yield per tonne of silage. Besides the positive effects of sealing system on top, other studies demonstrated that sodium benzoate applied at a 2-g kg^{-1} rate directly in the upper layer is suitable to preserve the nutrients of corn silage stored in bunker silos (Bernardes et al., 2014; Da Silva et al., 2014).

When the values for starch of the corn silage samples from the center and top of the bunkers were compared to the reference values, the top silages unexpectedly presented values greater than or equal to the reference value. The largest concentration of starch at the top can be explained by the slowly silo filling (up to five days) that occurs on several farms. In those cases, the concentration of starch increases as the plant matures in the field (Johnson et al., 1999).

The samples located at the center and top of the silo showed a correlation for the variables for nutritional value, with the exception of the ash content. However, we cannot state that those samples are similar, because the top area is more prone to spoilage. The increase in ash content indicates the extent of the loss of organic matter by aerobic deterioration (Dickerson et al., 1991), which may explain the lack of correlation between the top and center samples for this variable.

The aerobic deterioration also changes the fermentation profile of silage. Generally, the concentrations of organic acids, especially lactic and acetic acids, tend to decrease and pH values increase (Jonsson, 1989). It could explain the variations found in fermentation characteristics of the top silages compared with the center silages.

One aspect related to the assessment of corn silage is its fermentation quality. O'Kiely and Muck (1992) suggested some parameters commonly analyzed to assess the fermentation quality of corn silage, such as DM content, pH, concentration of volatile fatty acids, and microbial count. In the present study, the top and center silages showed no correlation for pH, lactic acid, butyric acid, and molds. The lack of correlation for those variables can be explained by the direct relationship between them and aerobic deterioration process (Pahlow et al., 2003) and because the top area of the silo is more susceptible to this process, as previously mentioned.

Conclusions

Overall, corn silage produced on intensive dairy farms in Brazil have satisfactory nutritive value for tropical climate conditions, especially in terms of starch concentration. However, some parameters, such as the concentration of the netral detergent fiber and its digestibility, are not suitable.

Also, a silo may contain two different types of silage: the silage located at the center, where fermentation occurs satisfactorily and oxygen does not have considerable negative effects, and the silage located at the top, where the chemical composition is poorer due to the intake of nutrients by undesirable microorganisms.

Thus, an important goal when producing silage is to make the conditions of the top area similar to those of the central part, so that few nutritional changes occur. This strategy prevents part of the feed from being discarded during feed-out and animals from having lower performance because of the conditions of the top silage. It is also important to guide nutritionists and producers when sampling silage to differentiate center from top.

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