Article

Assessment of corn silage in dairy farms in the municipality of Patos de Minas, Brazil

Received: may, 2018; Accepted: June, 2019

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Abstract
This study aimed to assess the corn silage used in 31 dairy farms in the municipality of Patos de Minas, State of Minas Gerais, Brazil. A questionnaire was applied with questions related to the property, the silage process, and the use of roughage. A cluster analysis was then performed to group the properties using the centroid method. Data were submitted to analysis of variance in a completely randomized design. The continuous variables and the discrete variables had their means compared using the Tukey test and the chi-square test, respectively, with 5% probability of type I error. Properties with low milk production were those with no technical assistance; they tended to have nonuniform silo faces and manual removal of silage, resulting in higher silage loss.

Keywords: aerobic stability, dairy cattle, face temperature, particle size, silage quality.

Introduction

The State of Minas Gerais has the largest dairy cattle herd in Brazil, with 5.4 million cows milked in 2015. It is also the largest national milk producer, with 27.1% of the Brazilian production (IBGE, 2016). Located in said state, the municipality of Patos de Minas stands out as the third largest milk producer in Brazil, with more than 1.4 billion liters (IBGE, 2015).

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The efficiency and sustainability of milk production systems are dependent on system-specific nutritional planning and management practices. Feedlots and semi-feedlots are the most used options in dairy farms, in response to the animals' improved genetic potential. In these systems, corn silage accounts for the highest share of the roughage volume (Bernardes et al., 2013; Bernardes et al., 2014).

The factors accounting for the use of corn for silage include its high productivity, energy concentration, production stability and nutritional value (Lauer, 1997). In some scenarios, corn silage may be the only roughage used and, therefore, its quality is a key point for dairy productivity.

High quality corn silage depends on management decisions and practices adopted before, during and after ensiling, such as selection of hybrids, fertilization, dry matter content at harvest, particle size, compaction, sealing, and management in the silage removal (Bernardes and Weinberg, 2014). Properties with higher production averages and higher volumes of milk are expected to be the ones with better silage quality, as they have greater access to technology and technical assistance.

Knowledge of silage production and its use in the municipality Patos de Minas dairy farms is important to support and improve food and management strategies adopted by both producers and the industry as well as research and public funding. This is expected to eventually benefit the milk production chain in the region (Bernardes et al., 2013).

Considering the importance of the municipality of Patos de Minas in the Brazilian milk chain, this study aims to assess the use and quality of corn silages in dairy farms in said region.

Material and methods

The field research was carried out in the municipality of Patos de Minas, southeast of the State of Minas Gerais. This region was chosen because of its constant development and increasing specialization in dairy production; it is also considered the dairy basin of the state of Minas Gerais (IBGE, 2015).

Thirty-one dairy properties were chosen at random to assess their corn silage usage. The collection of silage samples and further data occurred from June through September 2015.

A questionnaire was applied to the producers with 16 questions, as follows:

Five questions about the farm and the herd:

1) Daily milk production (L/day),
2) Composition of the herd: lactating cows, dry cows, heifers, and calves,
3) Average production (L/cow.day),
4) Milk quality: fat, protein, Somatic Cell Count (SCC), and Total Bacterial Count (TBC),
5) Price of 1 liter of milk.

Eleven questions about silage production techniques:

6) Distance between the crop and the silo,
7) Distance between the silo and the feeding place,
8) Time spent to seal the silo,
9) Cutting height of the plant,
10) Feed-out rate,
11) Silo coverage,
12) Handling of the tarpaulin,
13) Silage face management,
14) Destination of milk,
15) Agronomic and livestock consultancy,
16) Forage harvester: own or outsourced, self-propelled or conventional.

In addition to the questionnaire, an assessment also targeted the surface area, face temperature, particle size and dry matter (DM) content in the corn silages.

Metric evaluations of the height (h) and width (B: major base; b: minor base) of the silos were performed to calculate the area of the face as (B + b) / 2 b * h) (Cruz et al., 2001). Besides, the height was measured for the silage layer above the wall in the trench silos to identify over-supply. The area of the face above the silo wall was measured like the area of the bunker silo, i.e., ((B + b) / 2 b * h) (Cruz et al., 2001).

The silos were in the middle third of the use period. To calculate the average silage temperature (SILT), the temperature of at least three points were measured at the top, middle and bottom of the silage face in the silos with a skewer type digital thermometer. In larger silos, more points were collected to obtain representative data. The ambient temperature (AMBT) was also measured to calculate the difference between AMBT and silage temperature (DIFT).

In each silo, subsamples were collected in at least five points, in the form of "M" for bunker silos and in the form of "W" for trench silos: first, 5 cm were scraped; then collections were performed approximately 20 cm deep (Carvalho, 2011). The sub-samples were homogenized on a clean surface, as recommended by Carvalho (2011). Two samples were taken from each silo, one for evaluating particle size and the other for determining DM content. In larger silos, more than five points were collected for the sake of representativeness. The material was placed in a well-compacted plastic bag, sealed with adhesive tape and tagged with date of collection and name of the owner.

DM content was determined on the same day of collection, with a microwave oven at medium power. The use of a microwave oven reduces drying time and bacterial contamination, resulting in better appearance and product quality, without influencing the chemical composition of the dry material (Horsten et al., 1999). The samples were dried following the system recommended by Oliveira et al. (2015): 100 grams of sample were weighed with a precision scale and distributed in a plastic container with known weight. A plastic cup filled with approximately 150 mL of water was placed in the center of the container to moisten the environment and prevent the material from burning. Each sample was subjected to two cycles of 4 minutes, two cycles of 3 minutes, two cycles of 2 minutes and cycles of 1 minute until reaching constant weight. At each interval, the samples were turned over and the heated water exchanged to assure uniformness and avoid boiling. The last weight obtained was divided by the initial weight and multiplied by 100 to obtain the DM content in percentage.

One of the samples collected from each property was subjected to particle size separation using the Penn State Particle Size Separator system, to determine the range of variation in the average particle size. Following the system methodology (Heinrichs et al., 1999), after the initial sample weighing, eight series of five agitations were made, totaling 40 movements. Larger particles were retained in a 19-mm diameter sieve, intermediate particles were retained in an 8-mm sieve, and smaller particles were retained in a 4-mm sieve. There were also remaining particles shorter than 4-mm on the bottom of the equipment. The particles retained in each sieve were weighed; the weight was divided by the total weight of the sample and multiplied by 100 to obtain the values in percentage.

The front of the silage face condition was classified as uniform or nonuniform. The face was considered uniform when it had a flat silage removal surface and no height variations. In contrast, a nonuniform face had irregular surface due to variations in the thickness of the silage layer removed daily or to disturbances in the silage face during unloading.

A multivariate statistical analysis was performed for all variables. Cluster analysis was performed using the SAS® (2003) to group the properties using the centroid method. In this method, the distance between two clusters is defined as the distance between their mean vectors, also called centroid. This distance is then given by the squared Euclidean distance between the centroids of the two clusters (Mingoti, 2007).

For clustering, the following characteristics were noticed as important to describe milk production system and silage quality: milk production, average production, DM content, percentage retained in the 19-mm sieve, percentage retained in the 8-mm sieve, percentage retained in the 4-mm sieve, percentage retained in the <4-mm sieve, ambient temperature at the time of collection, average temperature of the silage, time spent to seal the silo, and feed-out rate in the 31 farms.

These characteristics were used to form multivariate data sets, which were used for cluster analysis in PROC CLUSTER considering the centroid method. In this analysis, the Root Mean Square Deviation (RMSD) values were obtained in relation to the number of clusters, which provided a graph for identification of the optimal number of clusters for maximum curvature. Complementarily, PROC TREE was used to visualize the dendrogram and to identify which farms belonged to the different clusters. The degree of dissimilarity that separated the clusters was 5%.

Farms were grouped into five clusters. However, two clusters consisted of only one property each and could not be submitted to variance and non-parametric analyses. As a result, only Clusters A, B and C were compared.

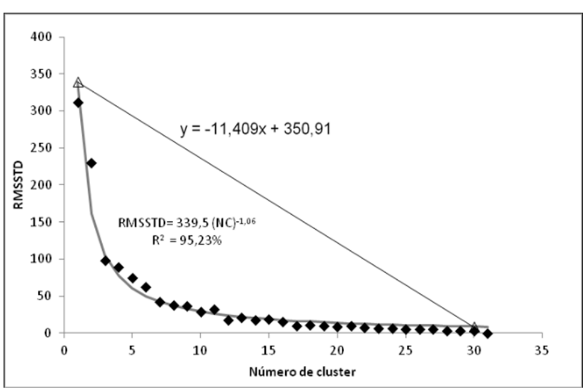
For the analysis of continuous variables, which can assume an infinite number of values between any two values, the response variables that did not meet the assumptions of the analysis of variance (additivity, error independence, normality of errors and homogeneity of error variance) had their data initially transformed. Then, an analysis of variance was performed in a completely randomized design, and the means of the factors were compared using the t test, adopting a 5% probability of type I error. For the response variables that did not meet the assumptions of the analysis of variance even upon transformation, a non-parametric analysis was performed using the Wilcoxon's test. This was the case for the following variables: time to seal the silo; surface area; milk protein; cutting height and distance between the silo and the feeding place.

For the analysis of discrete variables, which assume a finite number of values between any two values, a comparison of the means of the factors was performed using the chi-square test. This was the case for the following variables: face characteristics, form of silage removal, handling of the tarpaulin, technical assistance in the livestock domain, and technical assistance in the agronomic domain. All statistical analyses were performed with significance set at 5%.

Results and discussion

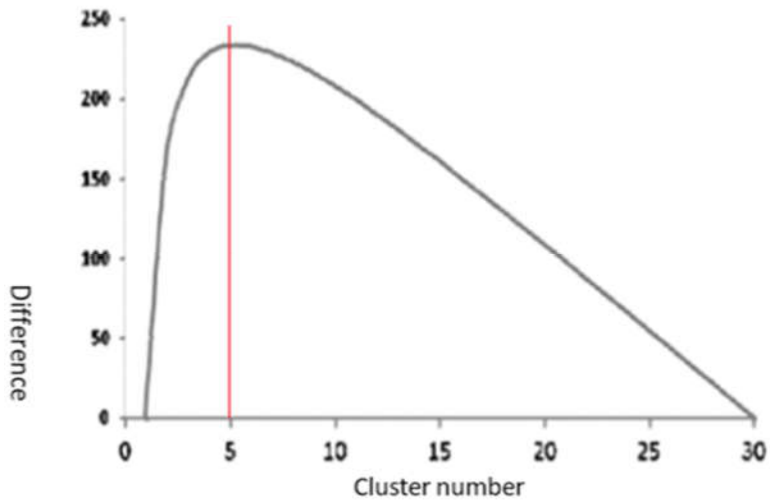
The RMSD index values were plotted on a graph according to the number of clusters, so that the longest distance between the equations is the ideal number of clusters. Figure 1 shows the adjusted exponential equation, its R^2 value and the linear equation used to find the difference between the equations.

Figure 1. Adjusted exponential equation, with its R^2 value, of the RMSD index values as a function of the number of clusters and the linear equation used to find the greatest distance between the equations, which corresponds to the ideal number of clusters.



The adjustment was adequate as the exponentially adjusted equation of the RMSD index values in function of the number of clusters had an R^2 value above 90%. Thus, the use of the maximum curvature method (Figure 2) is the most suitable for observing the greatest difference between the equations (Cecon et al., 2008). More specifically, having five clusters accounts for the greatest difference between the equations, which is therefore the optimal number of clusters.

Figure 2. Use of the maximum curvature method to observe the greatest difference between the linear and exponential equations, to determine the optimal number of clusters.



The dendrogram in Figure 3 shows the five clusters of farms with different characteristics related to milk production and corn silage.

Cluster A represented properties with higher volumes, average milk production, and lower levels of deteriorated silage on the silo surface. Cluster B had high milk production and high levels of deteriorated silage on the silo surface. Cluster C had low milk production and lower percentage of deteriorated silage on the silo surface (see Tables 1 and 2). The average milk production in Cluster C was lower compared to Clusters A and B, especially due to the lower number of lactating cows and the lower average production per cow.

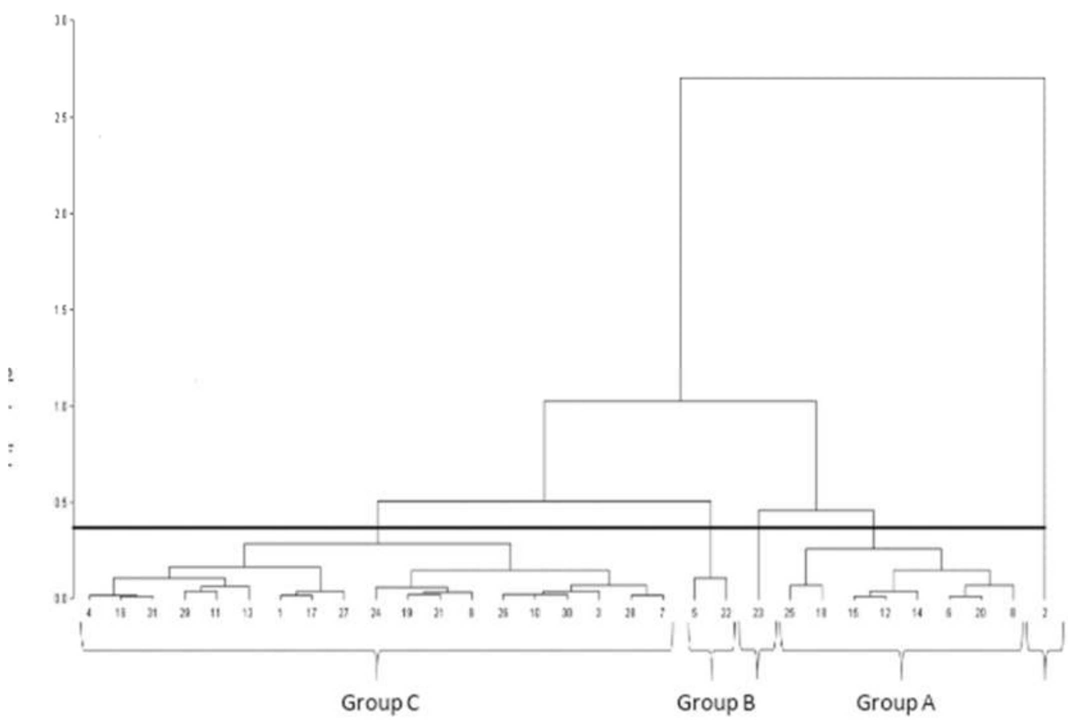
Table 1. Characteristics related to milk production per cluster of dairy farms in the municipality of Patos de Minas, State of Minas Gerais, Brazil, 2015.

Variables	Cluster*			p value	Coefficient of variation (%)
	A	B	C		
Milk production (L/day)	2031a	1275a	538b	<0.0001	6.77
Average production (L/cow/day)	21.1a	21.2a	16.1b	0.0363	26.5
Lactating cows (n°)	99.4a	61.5a	33.9b	<0.0001	9.96

* Cluster A: farms with higher milk production and lower level of deteriorated silage on the silo surface; Cluster B: farms with higher milk production and 100% deteriorated silage on the silo surface; Cluster C: farms with lower milk production and lower level of deteriorated silage on the silo surface.

For each characteristic, means followed by different letters differ by the t test (p<0.05).

Figure 3. Clusters of farms according to the characteristics related to milk production and corn silage.



The properties produced 150 to 5000 liters of milk per day. They had 12 to 200 lactating cows, predominantly of the Holstein breed. The average production was from 7 to 27 liters per cow per day. Only 52% of the properties had technical assistance in the livestock domain. Over half of the properties removed silage manually; 39% had a mixing wagon, out of which 50% had a scale and 35% had a silage cutter.

Table 2 compares the clusters regarding the qualitative characteristics related to technical assistance and the condition of the silo.

Table 2. Characteristics related to technical assistance and condition of the silo and silage during removal per cluster of dairy farms in the municipality of Patos de Minas, State of Minas Gerais, Brazil, 2015.

Variable	Cluster*			p value
	A	B	C	
Face condition (%)				
Uniform	50.0a	50.0a	26.3b	0.0071
Nonuniform	50.0b	50.0b	73.7a	0.0071
Form of silage removal (%)				
Silage Cutter	87.5a	50.0b	10.5c	0.0205
Shell	12.5b	50.0a	5.30b	0.0095
Manual	0.00b	0.00b	84.2a	0.0014
Tarpaulin handling (%)				
Open	62.5a	50.0a	36.8a	0.0808
Closed	37.5a	50.0a	63.2a	0.0808
Technical assistance in the livestock domain (%)				
Yes	87.5b	100.0a	26.3c	0.0230
No	12.5b	0.00c	73.7a	0.0230

Technical assistance in the agronomic domain (%)				
Yes	87.5a	50.0b	52.6b	0.0081
No	12.5b	50.0a	47.4a	0.0081
Deteriorated silage on the surface (%)				
Yes	75.0b	100.0a	63.2b	0.0010
No	25.0a	0.00b	36.8a	0.0010
Silage disposal (%)				
Low	100.0a	100.0a	84.2b	0.0007
High	0.00b	0.00b	15.8a	0.0007

* Cluster A: farms with higher milk production and a lower level of deteriorated silage on the silo surface; Cluster B: farms with higher milk production and 100% deteriorated silage on the silo surface; Cluster C: farms with lower milk production and a lower level of deteriorated silage on the silo surface.

For each characteristic, means followed by different letters differ by the t test ($p<0.05$).

The farms in Clusters A and B had ($p<0.05$) more uniform faces than those in Cluster C (see Table 2). This finding is probably due to the way silage is removed from the silos: 87.5% and 50% of the farms in Clusters A and B, respectively, used the silage cutter wagon to remove silage, and no property performed manual removal in these two clusters (see Table 2). In Cluster C, 84.2% of the properties removed the silage manually (see Table 2). The use of the silage cutter wagon containing a rotary cutting device allows the accurate removal of silage, enabling the cutting of the face from top to bottom (Bernardes and Weinberg, 2013).

No difference was found across the clusters for the handling of the tarpaulin in the silo ($p>0.05$) (see Table 2). It is still controversial whether or not the tarpaulin is placed on the exposed silage face during silo removal. A negative aspect is that placing the tarpaulin on the silage face can produce a warmer and more humid environment, which would allow further development of microorganisms that deteriorate the silage (Cruz *et al.*, 2001).

All farms in Cluster B had technical assistance in the livestock domain, while this feature was intermediate in Cluster A ($p<0.05$) and low in Cluster C ($p<0.05$) (see Table 2). Cluster A had the highest percentage of farms with agronomic assistance ($p<0.05$) compared to Clusters C and B (see Table 2).

Cluster B had a higher ($p<0.05$) percentage of farms with deteriorated silage on the surface compared to Clusters A and C. Silage disposal was higher ($p<0.05$) in Cluster C (see Table 2), which may be related to low levels of technical assistance in the livestock domain, manual removal of silage from the silo, and more nonuniform shape of silage (see Table 2). All these factors may have contributed to greater loss and, in effect, greater disposal of silage.

There was no difference ($p>0.05$) for the DM content in the silages across the clusters (see Table 3). The DM content of silages varied from 26 to 42% -- in fact, over 50% of the properties had a dry DM content of 32 to 35%, while only 6% had a DM content lower than 30% and only 6% had a DM content higher than 40%. Cruz et al. (2009) considered that the ideal DM content for corn silage should be 30 to 35%. Values below 30% entail losses of nutritional properties due to intense leaching and protein degradation, as well as the development of butyric acid producing bacteria. Values above 40% compromise the digestibility of the starch, especially in hard grains, when the grain reaches physiological maturity.

Dourado Neto and Fancelli (2000) observed that the optimal use of DM (i.e., with maximal fermentative quality and increased voluntary feeding) occurs when the grains are in the hard-flour point, close to the physiological maturation, with DM content between 33 and 37%. In this condition, vitreousness is the relationship between the vitreous endosperm and the total endosperm (Dombrink-Kurtzman and Bietz, 1993) and increases proportionally with the physiological maturity of the plant, especially in hard type grains, in which the high concentration of protein bodies leaves starch relatively unavailable for enzymatic degradation (Sullins and Rooney, 1975), compromising the digestibility of starch.

Table 3. Characteristics related to silage per cluster of dairy farms in the municipality of Patos de Minas, State of Minas Gerais, Brazil, 2015.

Variable	Cluster*			p value	Coefficient of variation (%)
	A	B	C		
Dry matter (%)	34.5a	31.0a	33.6a	0.5008	11.1
19-mm sieve (%)	5.25a	4.00a	7.42a	0.7349	42.9
8-mm sieve (%)	62.5a	56.5a	59.5a	0.4763	12.0
4-mm sieve (%)	23.5a	29.0	24.6a	0.6173	28.5
<4-mm sieve (%)	8.75a	10.5a	8.47a	0.7372	40.0
Face area (m^2)	21.4a	11.7b	11.1b	0.0012	45.4
Feed-out rate (m/day)	0.30a	0.23a	0.40a	0.0672	50.4
Ambient Temperature at collection (°C)	29.4a	28.5a	30.1a	0.7846	12.3
Average Temperature in silo (°C)	31.9a	29.2a	31.0a	0.3781	8.03

* Cluster A: farms with higher milk production and a lower level of deteriorated silage on the silo surface; Cluster B: farms with higher milk production and 100% deteriorated silage on the silo surface; Cluster C: farms with lower milk production and a lower level of deteriorated silage on the silo surface.

For each characteristic, means followed by different letters differ by the t test (P <0.05).

No difference (p>0.05) was found for the granulometry variables (19 mm, 8 mm, 4 mm, and <4 mm) across the clusters (see Table 3). Using the PenState method, the following mean values were found: 6.83%; 60.29%; 24.35% and 8.51%, respectively. According to Heinrichs and Kononoff (2002), the ideal granulometry values for corn silage after moving the PenState trays should be 3-8% of particles retained in the 19-mm sieve, 45-65% in the 8-mm sieve, 30-40% in the 4-mm sieve, and <% at the bottom. These values characterize silages with effective fiber profile, as they have standard percentages for larger diameter sieves. As such, it seems that the 4-mm and <4-mm sieves were the only ones with different values from those recommended by Heinrichs and Kononoff (2002).

The average temperature of the environment at the time of collection was approximately 30º C, with a minimum of 22º C and a maximum of 35º C. The average temperature found inside the silos varied from 26 to 37º C. No statistical difference (p>0.05) was found for ambient temperature at the time of collection and average silage temperature across the clusters (see Table 3). In general, the silage temperatures were slightly higher than the ambient temperature (<2° C for all clusters). This points to no break in the aerobic stability of the silage, as aerobic instability ensues when the difference between the silage temperature and the ambient temperature is higher than 2º C (Moran et al., 1996; Siqueira et al., 2005; Jobim et al., 2007).

No difference (p>0.05) was found for the feed-out rate of the faces across the clusters. However, Cluster A had a larger surface area compared to Clusters B and C (see Table 3), probably due to the larger herd. The correct silo removal, taking into account the silage removal rate, is a way to control aerobic deterioration in the use stage (Borreani and Tabacco, 2012). Bolsen (2003) recommends a daily feed-out rate of 15 to 30 cm thick; however, a removal of at least 45 cm would be necessary in hot, humid places to maintain food quality. The observed feed-out rate values (23-40 cm, see Table 3) were within the range recommended by Bernardes and Weinberg (2013).

The distance between the silo and the crop varied from 10m to 15km. This difference, combined with the volume of silage produced, influenced the time spent to seal the silo (1 to 7 days). The distance between the silo and the place where the animals are fed varied from 5 to 200 m.

The cutting height at the time of ensiling varied from 15 to 40 cm, with almost 70% of the farms ensiling from 20 to 25 cm high. This cutting height is used more often when the aim is to increase the production of dry phytomass per hectare, which reduces or dilutes the cost per ton of the silage produced (Cruz et al., 2001). This may have been one of the objectives of the farmers, which resulted in the adoption of a low cutting height of corn plants at the time of ensiling. Notwithstanding, increased cutting height ensues improved nutritional quality of the silage, as it increases energy concentration, reduces the NDF (Neutral Detergent Fiber) content. It also improves the digestibility of the DM of the plant because it reduces the thatch/cob ratio (Mendes, 2006).

There was no difference ($p>0.05$) across the clusters for the milk quality variables, such as milk fat (MF), milk protein (MP), somatic cell count (SCC) and total bacterial count (TBC) (see Table 4).

Table 4. Characteristics related to the quality and price of milk per cluster of dairy farms in the municipality of Patos de Minas, State of Minas Gerais, Brazil, 2015.

Variables	Cluster*			p value	Coefficient of variation (%)
	A	B	C		
Milk fat (%)	3.67a	3.84a	3.80a	0.2772	5.32
Milk protein (%)	3.29a	3.26a	3.30a	0.8700	
Somatic cells (1,000 x SCC/mL)	363a	266a	429a	0.6080	9.02
Bacterial count (1,000 x CFU/mL)	7.25a	6.50a	14.8a	0.0601	28.5
Milk price (BRL/L)	1.10a	1.10a	1.02a	0.2580	6.79

SCC: Somatic cell count; CFU: Colony Formation Unit; BRL: Brazilian Real.

* Cluster A: farms with higher milk production and a lower level of deteriorated silage on the silo surface; Cluster B: farms with higher milk production and 100% deteriorated silage on the silo surface; Cluster C: farms with lower milk production and a lower level of deteriorated silage on the silo surface.

For each characteristic, means followed by different letters differ by the t test ($p<0.05$).

The milk chain in Brazil has undergone several changes. The growth of per capita income in recent years has stimulated the consumption of dairy products, increasing demand and consumer requirements (e.g., milk quality) (EPAMIG, 2010). This study observed that all dairy companies pay for quality, taking into account some indicators such as acidity levels, somatic cell count (SCC), total bacterial count (TBC), fat and protein content. The concentrations ranged from 3.47 to 4.27 for fat, and 3.01 to 3.85 for proteins. The average somatic cell count was 395 thousand SCC / mL, while the TBC was 12 thousand CFU / ml.

Inadequate levels of such indicators may reduce industrial performance, which could compromise the validity of dairy products, resulting in low quality food for the end consumer (Mattiello et al., 2018). As a result, Normative Instruction No. 62, as of July 2016, requires new quality standards, with a maximum of 4.0 x 105 SSC/mL, a maximum of 1.0 x 105 CFU/ml, a minimum concentration of 2.9% for protein and 3.0% for fat, as well as 0.14 to 0.18 g of lactic acid/100ml. The percentages of fat and protein, as well as the bacterial and somatic cell counts, found in this study (see Table 4) meet the standards required by Normative Instruction No. 62.

There was no difference ($p<0.05$) for the average price of milk (see Table 4) across the clusters. The average price for a liter of milk was BRL 1.06 (Brazilian Real), ranging from BRL 0.88 to 1.21, with 65% of the milk produced for two dairy companies, COOPATOS and NESTLE.

Conclusions

Properties with low milk production are those with no technical assistance. They tend to have nonuniform silo faces and manual removal of silage, resulting in greater silage loss.

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Avaliação da silagem de milho em fazendas leiteiras de Patos de Minas, MG

Resumo
O objetivo com este estudo foi avaliar as silagens de milho utilizadas em propriedades leiteiras do município de Patos de Minas, MG. Foram visitadas 31 propriedades do município, onde foi aplicado um questionário com questões relacionadas à propriedade, ao processo de ensilagem e à utilização do volumoso. Foi realizada análise de cluster para fazer o agrupamento das propriedades avaliadas, utilizando o método do centróide. Os dados foram submetidos à análise de variância em delineamento inteiramente casualizado e as médias das variáveis contínuas foram comparadas pelo teste de Tukey, enquanto que as médias das variáveis discretas, pelo teste de qui-quadrado, com probabilidade de 5% para ocorrência do erro tipo I. As propriedades com baixa produção de leite são caracterizadas por ausência de consultoria técnica e tendem a apresentar painéis de silos desuniformes, com retirada manual, resultando em maior descarte (perda) de silagem.

Palavras-chave: bovinocultura leiteira, estabilidade aeróbia, qualidade de silagem, tamanho de partícula, temperatura do painel.

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