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Study on the practices of silage production and utilization on Brazilian dairy farms

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ABSTRACT

Dairy farmers across Brazil were invited to participate in a study on silage production and utilization practices. Two hundred sixty farmers filled out a questionnaire, which was made available on a website. The questionnaire consisted of 14 questions, including information about the characteristics of the herd (n = 3), the crop(s) used in the ensiling process, the use of additives, the harvest (n = 3), the type of silo (n = 1), aspects related to sealing (n = 2), and management practices applied during feed-out (n = 3). Farmers were also asked a final question about the main barriers they faced when producing and using silage. The main dairy-producing regions of Brazil had a strong influence on the number of participants. The profiles of farmers were heterogeneous and divided into 5 groups, which was considered a positive attribute of the study, allowing better analysis and assessment of current circumstances. Corn was the most widely grown crop for silage. Sorghum, tropical grasses, and sugarcane were the other species most cited. Additives were used by a small number of farmers (27.7%). Approximately 40% of farmers still depended on loaned equipment or outsourced services. The pull-type forage harvester was the main piece of equipment used on dairy farms (90.4%). Only 54.6% of respondents answered that they sharpen their harvester knives daily. Horizontal silos (bunker and stack) were the structures most commonly used to store silage. Most farmers sealed silos with double-sided plastic film (black-on-white) and with soil. However, almost one-fifth of all farmers still use black plastic. Manual removal of silage from the silos was practiced at most farms (i.e., the lack of equipment was also reflected in the stage of silage utilization). Disposal of spoiled silage before inclusion in the livestock feed was not a common practice on the farms. The main barriers encountered on the farms were lack of equipment, lack of manpower, and climatic variations. The results of this research may guide researchers, industries, extension workers, and governments to seek efficiency in milk production on farms using silage in the diet of livestock throughout the year or during part of the year in Brazil.
Key words: dairy industry, feeding practice, tropical silage, Brazil

INTRODUCTION

Traditionally, the standard diet of dairy cattle in Brazil is based on pasture. However, forage conservation has been an important agricultural activity since dairy activity began at the beginning of the last century (Cotrim, 1913; Athanassof, 1943). In tropical environments, hay production presents certain obstacles due to high humidity and frequent rainfall (Adesogan, 2009). Artificial dryers are expensive for farmers, and buildings are often not available (‘t Mannetje, 1999). Consequently, ensiling is the main method for forage preservation in countries with hot and humid climates (Adesogan, 2009; Reiber et al., 2009; Lima-Orozco et al., 2013). Since the implementation of silage as part of the dietary plan of dairy cattle over a hundred years ago, no data have been published in the literature describing practices of its production and utilization in Brazil. Brazil has no annual census for farmers or official statistics about this practice, as is found in countries where the dairy industry is more developed. The only Brazilian data on the production of silages are found in the book World Silage (Wilkinson and Toivonen, 2003); however, these data are limited to some characteristics of the Brazilian state of Minas Gerais.

Milk production in Brazil has increased by approximately 3-fold in the last 30 yr, from 11 billion liters per year in the early 1980s to over 30 billion liters in 2012 (USDA-FAS, 2012). In terms of volume production, Brazil is considered to be the fourth largest milk producer in the world and the second largest in the Americas (USDA-FAS, 2012). Considering the 5 countries that produce the most milk, Brazil, along with China and India, has demonstrated the greatest growth rate in milk production in recent years (FAO, 2013). However, this growth has been uneven and disorga-

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nized in the country, with the increasing adoption of intensive systems, although the family farm and low professionalization still dominate this production chain (IBGE, 2006). Dairy activity in Brazil also faces a geographic shift because production has migrated to the midwest region and lost strength in some states of the south-central region, especially São Paulo (EMBRAPA, 2011); in this region, sugarcane cultivation has become more attractive to producers. This new geography poses challenges for silage producers, especially with regards to climate, because the midwest region of Brazil has higher temperatures and a longer dry period than the south-central region.

Because silage is the main source of energy and fiber in the diets of dairy cattle in Brazil throughout the year in intensive systems or during part of the year in systems that use pastures (Costa et al., 2013), it is necessary to provide information to the dairy industry that depicts the management applied in farms across the country, with the objective of organizing the growth of this activity. Several studies have shown that the production costs of conserved forage are negatively correlated with the profitability of dairy farms (Haden and Johnson, 1989; Hansen et al., 2005). Adkinson et al. (1993) illustrated that in pasture-based milk production systems, as is the case for many farms in Brazil, the use of high-quality silage in the diet enhances milk production and income over feed costs. In addition to the economic issues, increased efficiency of nutritional management on dairy farms reduces the emission of greenhouse gases, especially in developing countries and among small farmers, as is the case for Brazil (Gerber et al., 2011).

Thus, the objective of the present study was to understand the practices of silage production and utilization on dairy farms in Brazil so that feeding strategies and management by the farmers and industries and lines of research and credit by the scientific community and governments may be defined and improved, thereby benefiting the dairy industry in Brazil.

MATERIALS AND METHODS

Dairies

A total of 500 dairy farmers located in 26 Brazilian states in which milk production was the sole or main agricultural activity on the farm were invited to participate in this survey. These farmers were specifically identified through a website database (www.milkpoint.com.br) to represent different regions of the country (south, southeast, midwest, northeast, and north) and were then contacted via e-mail to determine their interest in participating in this study. A total of 272 farmers completed the survey questionnaire; however, 12 responses were incomplete. Thus, 260 questionnaires were used in the study, which represented the 5 regions and 23 states. Only farmers in the states of Amazonas, Amapá, and Roraima (Amazon region) did not respond to our invitation, possibly because dairy farming is less important in these regions.

Survey Data Collection

A webpage was used to complete the questionnaire and for data collection (www.milkpoint.com.br/pesquisa-silagem) and was available between the months of January and February 2012. These months were chosen because farmers are preparing to harvest crops at this time. When accessing the webpage, the user first registered and then received information on how to complete the form. All 260 farmers completed the survey in 50 d. The confidentiality of all participants was guaranteed.

Survey Questions

Fourteen questions on the survey measured qualitative characteristics, as follows: (1) what is average daily production of the farm?; (2) what is average production per cow per day?; (3) which breed do you use?; (4) what forages do you feed?; (5) do you apply additives in the ensiling process (yes or no)?; (6) which service do you use (own or hired)?; (7) which type of forage harvester do you use (pull-type or self-propelled)?;(8) how often do you sharpen the harvester knives (in the beginning, daily, every 2 d, or more than every 2 d)?; (9) how is the silage stored (bunker, stack, pressed bag, or wrapped bale)?; (10) which type of plastic film do you cover (black or black-on-white)?; (11) what material do you place on top of the plastic film?; (12) do you unload silage manually or mechanically?; (13) what portion of the face width is removed daily (entire, half, a third, or a quarter)?; and (14) do you discard spoilage silage (yes or no)? Farmers were also asked one final question, which asked about the main barriers faced when making and using silage. This question was asked without pre-established alternatives so those farmers had the opportunity to mention the maximum range of possible barriers in silage production.

Data Analysis

The differences between the qualitative data were compared using the Pearson χ^2 test for contingency tables. A cluster analysis was conducted, which allowed grouping of the farms showing similarities (less variance within groups) and differences (higher variance between groups), using the Ward method and smallest

Euclidean distance (Statistica Software, 2009). Finally, technical indicators were used to define each group, and contingency tables with qualitative variables were constructed. Technological levels of the farms were used to divide the groups, taking into account the parameters of milk production on the farms, productivity of the cows, and breed (Table 1). The groups (technological levels) were identified as follows: group 1 was characterized by lowest technological level; more than 70% of the farms produced up to 499 L/d and had no properties with yield >999 L/d and a greater number of farmers raised Girolando cattle; in group 2 were the farms with technological level higher than group 1 and lower than group 3; group 3 showed intermediate technological level (51.3% of the farms produced 500–1,500 L/d); in group 4 were the farms with the lower milk production per day and animals less productive than the farms of the group 5; group 5 showed the highest technological level. In this group, cows had productivity greater than 20.0 L of milk/d, 95.9% of the farms produced more than 1,500 L/d and had no farms producing less than 1,000 L/d.

RESULTS AND DISCUSSION

Characteristics of the Properties

Of the farmers who filled out the questionnaire, 33.7% had farms in Minas Gerais, 13.2% in Paraná, 13.1% in São Paulo, 11.9% in Goiás, 8.8% in Rio Grande do Sul, 4.6% in Santa Catarina, and 3.8% in Bahia. The 7 states mentioned above, which are located in the south, southeast, midwest, and northeast regions, produce over >1 million liters of milk per year and are the largest milk producers in Brazil, producing approximately 80% of the national volume (IBGE, 2011). The other states represent fewer than 2% of the farmers who responded to the survey questionnaire. Based on the assessment of daily milk production, 45.4% of the farms produced <500 L of milk/d, 22.7% produced between 500 and 999 L, 10.0% produced between 1,000 and 1,499 L , 9.6% produced between 1,500 and 1,999 L, and large producers (>2,000 L of milk/d) accounted for 12.3% of respondents (Table 1). Data from the last agricultural census conducted in Brazil (IBGE, 2006) revealed that small producers or family farms represent the majority (58%) in the dairy industry. Another finding of the Brazilian Institute of Geography and Statistics (IBGE, 2006) was that, on average, Brazilian dairy farms have only 24 cows. In a recent survey conducted in the state of Santa Catarina, located in the southern region of Brazil, Costa et al. (2013) studied 3 production systems (i.e., extensive, pasture-based, and semi-intensive) and determined that daily milk production of >300 L/d occurred only among producers who adopted a semi-intensive system (pasture and supplementation with silage and concentrate).

A total of 54.6% of the farms had, on average, cows that producing between 10.0 and 19.9 L of milk/d, followed by those with productivity from 20.0 to 29.9 L of milk/d (27.7%), <9.9 L of milk/d (13.1%), and ≥30 L of milk/d (4.6%; Table 1). If considering cows with productivity up to 19.9 L of milk/d, these accounted for more than two-thirds of the participants. This is

Table 1. Characteristics of the herds on Brazilian dairy farms studied according to hierarchical grouping

Item	Overall	Group (technological level)[1]					*P*-value
		1	2	3	4	5	
Milk production, L/d							<0.001
≤499	45.4	82.8	75.0	41.0	40.0	0.0	
500–999	22.7	17.2	8.3	35.9	36.7	0.0	
1,000–1,499	10.0	0.0	4.2	15.4	18.9	4.1	
1,500–1,999	9.6	0.0	8.3	2.6	3.3	38.8	
≥2,000	12.3	0.0	4.2	5.1	1.1	57.1	
Productivity, L/cow per day							<0.001
≤9.9	13.1	22.4	33.3	5.1	12.2	0.0	
10.0–19.9	54.6	58.6	62.5	35.9	65.6	40.8	
20.0–29.9	27.7	17.2	4.2	51.3	21.1	44.9	
≥30	4.6	1.7	0.0	7.7	1.1	14.3	
Breed, %							<0.001
Girolando	51.9	72.4	87.5	7.7	53.3	42.9	
Holstein	36.2	17.2	4.2	66.7	34.4	53.1	
Jersey	10.4	6.9	8.3	25.6	10.0	4.1	
Others	1.5	3.4	0.0	0.0	2.2	0.0	

[1]Group 1: more than 70% of the farms produced up to 499 L/d and no farms produced >999 L/d; group 3: 51.3% of the farms produced 500–1,500 L/d; group 5: 95.9% of the farms produced >1,500 L/d and had no farms producing <1,000 L/d. Groups 2 and 4 were intermediate between groups 1 and 3 and 3 and 5, respectively.

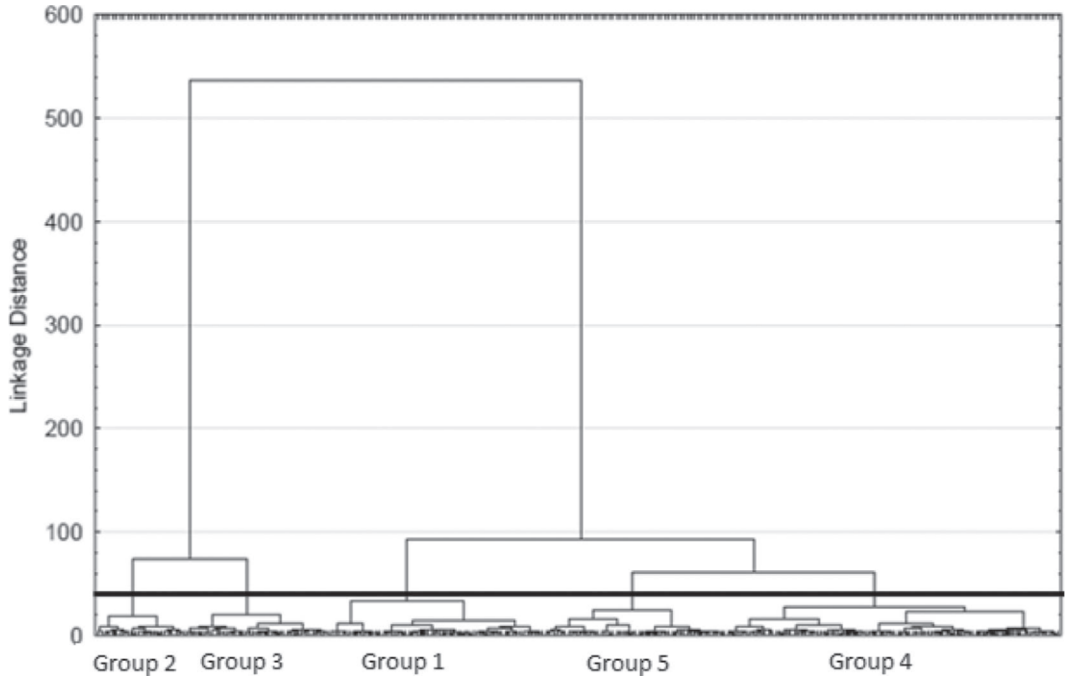

Figure 1. Ascending hierarchical groupings of Brazilian dairy farms. Ward's method and Euclidean distance were taken into consideration in the calculation of these results. Group 1: more than 70% of the farms produced up to 499 L/d and no farms produced >999 L/d; group 3: 51.3% of the farms produced 500–1,500 L/d; group 5: 95.9% of the farms produced >1,500 L/d and had no farms producing <1,000 L/d. Groups 2 and 4 were intermediate between groups 1 and 3 and groups 3 and 5, respectively.

an important characteristic to highlight because among the 10 major milk-producing countries in the world, Brazil has the least productive cows, ranking only above India (USDA-FAS, 2012). Indeed, Brazil ranks among the world's top milk producers because of the number of animals, not because of their productivity.

The Girolando breed (5/8 Holstein: 3/8 Gyr) was the breed most utilized by the respondents (51.9%). This breed makes up a large percentage of the dairy business in Brazil because of its relationship to zebu cattle, which have characteristics of adaptability to tropical conditions, including high heat resistance, resistance to external and internal parasites, and satisfactory milk production (Silva et al., 2011); however, they are not specialist milk producers. The Holstein and Jersey breeds accounted for 36.2 and 10.4% of the animals, respectively. Other breeds, usually zebu, were utilized by only 1.5% of the farmers surveyed.

The dendrogram reported in Figure 1 shows the formation of 5 groups at different technological levels taking into account the Euclidean distance of 40 units. Group 5 differed significantly ($P < 0.001$) from the other groups because 57.1% of the farms produced more than 2,000 L of milk/d and use Holstein cows (53.1%). Conversely, groups 1 (72.4%) and 2 (87.5%) were represented by small farmers ($P < 0.001$) who produced <499 L of milk/d, raised Girolando cattle, and most likely adopted less-specialized production systems.

Crops for Silage Production

Results regarding the use of silage crops are displayed in Table 2. Corn was the crop most widely cited by farmers. Two hundred fifteen respondents (82.7%) reported that they used corn alone or in combination with other forage species. This finding may be explained by the positive characteristics of this species, including high ensilability, productivity, and nutritional value (Allen et al., 2003). Additionally, this crop has been traditionally grown since the beginning of the last century (Cotrim, 1913) and is well adapted to the environmental conditions of Brazil. Other crops mentioned were sorghum (27.7%), whose use has been increasing as a feed in the tropics (Lima-Orozco et al., 2013), tropical grasses (23.5%), especially elephant grass and cultivars of the genus *Panicum*, and sugarcane (21.5%). Other crops accounted for 6.5% of the silage crops. These included oats, rye, barley, and wheat, which are specifically grown in the southern region of the country (Meinerz et al., 2011) due to the favorable climatic conditions (autumn and winter with milder temperatures and rainy, between 22°32′S and 33°41′S; Neres et al., 2011). Group 3 contained the farmers that most utilized ($P = 0.03$) corn for silage (92.3%), and this was the only group to not use sugarcane. Group 2 used the least amount of corn ($P = 0.03$) for silage production (62.5%); therefore, group 2 included the farmers

Table 2. Crops utilized in the silage production process on Brazilian dairy farms according to the hierarchical grouping

Item	Overall	Group (technological level)[1]					P-value
		1	2	3	4	5	
Corn, %							0.03
No	17.3	20.7	37.5	7.7	16.7	12.2	
Yes	82.7	79.3	62.5	92.3	83.3	87.8	
Sugarcane, %							<0.001
No	78.5	65.5	62.5	100.0	83.3	75.5	
Yes	21.5	34.5	37.5	0.0	16.7	24.5	
Sorghum, %							0.18
No	72.3	70.7	45.8	84.6	75.6	71.4	
Yes	27.7	29.3	54.2	15.4	24.4	28.6	
Tropical grasses, %							<0.001
No	76.5	74.1	41.7	94.9	82.2	71.4	
Yes	23.5	25.9	58.3	5.1	17.8	28.6	
Others, %							<0.001
No	93.5	100.0	95.8	82.1	98.9	83.7	
Yes	6.5	0.0	4.2	17.9	1.1	16.3	

[1]Group 1: more than 70% of the farms produced up to 499 L/d and no farms produced >999 L/d; group 3: 51.3% of the farms produced 500–1,500 L/d; group 5: 95.9% of the farms produced >1,500 L/d and had no farms producing <1,000 L/d. Groups 2 and 4 were intermediate between groups 1 and 3 and groups 3 and 5, respectively.

that mainly cultivated other species, such as tropical grasses, sorghum, and sugarcane.

Ensiling Process

The silage production processes are displayed in Table 3. Only 27.7% of respondents said that they applied an additive when ensiling the crops. An analysis conducted in southern Brazil, including 120 dairy farms, determined that 18% of all farmers applied additives in corn silage and that all of these additives were bacterial inoculants (Bernardes et al., 2012a). Wilkinson and Toivonen (2003) reported that, in many countries, the practice of using additives is insignificant, possibly reflecting doubts about their cost effectiveness. Those authors also commented that biological additives are preferred by farmers because new products are being launched to improve the aerobic stability of cereal silages. In other countries, it seems that additives are more common among farmers. For example, in Israel, where wheat silages are widely used in the diet of dairy cows, a study indicated that approximately 47% of the silages were treated with additives, most of which were chemicals or bacterial inoculants (Weinberg et al., 2009). High quality silage can be made without the use of additives assuming that producers have control over many management aspects. However, silage additives can be useful in different circumstances. For example, they have been used to prevent the production of butyric acid in wet silages. In addition, additives are used to reduce DM losses and preserve nutrients during fermentation and feed-out phase (Kung et al., 2003). In the current study, group 5 was the major group of farmers that used additives (49.0%) in silages relative to the other groups ($P = 0.007$). The respondents with higher purchasing power and who were possibly more informed made greater use of technologies that improve the silage conservation process.

When questioned about the mode of services in ensiling (personal or outsourced), 58.8% of respondents answered that they used their own equipment and 41.2% reported outsourcing. Although the questionnaire presented only these 2 options to the respondents, those who responded that they outsourced this service did not always rent equipment; they sometimes borrowed the equipment from neighbors, the municipal government, or cooperatives to which they belonged. This scenario is reflected when grouping the farmers, as groups 1 and 4 were those who most frequently reported outsourcing the ensiling process ($P = 0.004$). The farmers in group 1 (considered to be low-tech) rarely rented machines (i.e., they were loaned from other farmers or entities).

The majority of harvesters were pulled by a tractor (90.4%), followed by farmers using self-propelled (9.6%) harvesters. The use of pull-type forage harvesters is still very common in Brazil mainly because of the high cost of self-propelled harvesters. This scenario is different from that observed in other countries that have a tradition of forage conservation. According to Muck and Shinners (2001), worldwide sales of traditional ensiling machines decreased from 7,000 units in 1990 to 3,500 in 1995; in turn, the sale of self-propelled machines increased from 1,800 to 2,500 units within the same period. A recent survey determined that the use of traditional harvesters

Table 3. Characteristics of the practices for production and utilization of silages on Brazilian dairy farms according to the hierarchical grouping

Item	Overall	Group (technological level)[1]					*P*-value
		1	2	3	4	5	
Additive, %							0.007
No	72.3	81.0	83.3	71.8	75.6	51.0	
Yes	27.7	19.0	16.7	28.2	24.4	49.0	
Service, %							0.004
Own	58.8	51.7	79.2	56.4	50.0	75.5	
Outsourced	41.2	48.3	20.8	43.6	50.0	24.5	
Harvester, %							<0.001
Pull-type	90.4	98.3	79.2	87.2	96.7	77.6	
Self-propelled	9.6	1.7	20.8	12.8	3.3	22.4	
Frequency of knife sharpening, %							<0.001
Beginning	26.9	79.3	33.3	30.8	1.1	6.1	
More than 2 d	7.3	12.1	20.8	10.3	1.1	4.1	
Every 2 d	11.2	5.2	16.7	7.7	14.4	12.2	
Daily	54.6	3.4	29.2	51.3	83.3	77.6	
Silo, %							<0.001
Stack	38.1	51.7	70.8	48.7	26.7	18.4	
Bunker	60.4	48.3	25.0	48.7	73.3	77.6	
Pressed bag	1.5	0.0	4.2	2.6	0.0	4.1	
Plastic films, %							<0.001
Black	18.8	19.0	25.0	46.2	12.2	6.1	
Black-on-white	77.7	81.0	75.0	48.7	84.4	85.7	
Both	3.5	0.0	0.0	5.1	3.3	8.2	
Weight on the plastic, %							0.01
None	8.8	12.1	4.2	5.1	10.0	8.2	
Tires	5.8	3.4	0.0	7.7	6.7	8.2	
Soil	69.2	74.1	83.3	66.7	72.2	53.1	
Soil and tires	8.1	5.2	4.2	5.1	3.3	24.5	
Other	8.1	5.2	8.3	15.4	7.8	6.1	
Silage removal, %							<0.001
Manual	85.0	100.0	100.0	71.8	93.3	55.1	
Mechanical	15.0	0.0	0.0	28.2	6.7	44.9	
Removal of the face, %							<0.001
25%	32.3	50.0	62.5	20.5	23.3	22.4	
50%	18.8	24.1	12.5	17.9	18.9	16.3	
75%	19.6	10.3	12.5	33.3	23.3	16.3	
100%	29.2	15.5	12.5	28.2	34.4	44.9	
Discard spoiled silage, %							0.89
Yes	11.2	12.1	8.3	15.4	10.0	10.2	
No	88.8	87.9	91.7	84.6	90.0	89.8	

[1]Group 1: more than 70% of the farms produced up to 499 L/d and no farms produced >999 L/d; group 3: 51.3% of the farms produced 500–1,500 L/d; group 5: 95.9% of the farms produced >1,500 L/d and had no farms producing <1,000 L/d. Groups 2 and 4 were intermediate between groups 1 and 3 and groups 3 and 5, respectively.

may result in silages with low particle size uniformity and a predominance of long particles (Bernardes et al., 2012a); hence, this cutting pattern could result in further deterioration of the silage because larger particles hinder compaction of the mass and increase oxygen penetration due to higher porosity (Muck et al., 2003). This fact is verified by the appearance of mold on the silo face. The unevenness of the particles may also compromise the nutrition of dairy herds with medium- to high-production potential because, due to the rejection of larger particles in the trough, animals may not eat the amount of fiber needed to maintain rumen health (Heinrichs et al., 1999). Furthermore, longer chop results in less grain being cracked or damaged. Uncracked grains in corn and sorghum silages may be undigested and end up in ruminant feces. Mechanical processing of grains by forage harvester is an important way to break the outer surface and facilitate digestion of starch within the grain (Roberge et al., 1998). Bal et al. (2000) showed that processing corn silage improved DMI, starch digestion, and lactation performance. To minimize such problems when utilizing pull-type harvesters, special care should be taken in adjusting the machine, especially adjustments related to the sharpening of knives and clearance between the cutterhead and shear bar. Most of the group 1 farmers ($P < 0.001$) used pull-type harvesters (98.3%), followed by groups 4 and 3. Farmers of group 5 were those that most used ($P < 0.001$) self-propelled harvesters (22.4%).

Only 54.6% of the respondents indicated that they sharpened the knives of the harvesters daily (Table 3). The others reported sharpening only at the beginning of the harvest (26.9%), every 2 d (11.2%), and less frequently than every 2 d (7.3%). Farmers in groups 4 and 5 were more concerned ($P < 0.001$) with performing this type of operation, most likely because they have greater knowledge of the benefits that this procedure has on the quality of silage conservation. In contrast, group 1 farmers, which represent farmers from small farms, were less likely to sharpen harvester knives daily ($P < 0.001$). Indeed, only 3.4% of the group 1 farmers utilized this procedure, and the majority of farmers in group 1 sharpened the knives only at beginning of the harvest (79.3%). The other groups (2 and 3) showed a more homogeneous distribution for this type of management in the harvesting process. The 2 main issues that must be addressed in the maintenance of forage harvesters is to keep the knives sharp and to adjust the knives and shear bar (O'Dogherty, 1982; Shinners, 2003). The use of dull knives and poor adjustment of the equipment result in collected material that is torn rather than cut, which in some cases may halt the machine because of material stuck between the knives and shear bar, resulting in wasted fuel and poor cut quality (Wild et al., 2011). Tearing of the material results in long particles, low cut uniformity, and therefore, problems in compaction of the mass (Shinners, 2003).

The majority of the farmers had a bunker silo on their farms (60.4%), 38.1% used stack silos, and only 1.5% used pressed-bag silos (Table 3). Farmers from groups 1 and 2 ($P < 0.001$) mainly used stack silos (51.7 and 70.8%, respectively). Possibly because of their lower investment power, these farmers often opted for strategies that did not require major expenses, as in the case of stack silos, where the main investment is the plastic film (Savoie and Jofriet, 2003). Dry matter losses of stack silages can be high because of the low density of such silages (Weinberg and Ashbell, 2003). Because stack silos have a low density, they must be packed using heavy tractors in thin layers (<20 cm) and sealed rapidly to minimize air infiltration and oxidization (Savoie and Jofriet, 2003). Farmers from groups 4 and 5 mainly utilized bunker silos (73.3 and 77.6%, respectively), most likely because of their greater investment power. A major advantage of bunker silos is that they allow handling large amounts of feed very rapidly (Savoie and Jofriet, 2003). They are the preferred storage system on most large feedlot operations. In bunker silos, the surface to be covered is large in relation to the silo content; therefore, the quality of cover is important (Bolsen et al., 1993).

Double-sided plastic film was the most cited (77.7%) by respondents for sealing silos, followed by a dark-colored film (18.8%), or both (3.5%). Almost one-fifth of farmers still utilized black plastic for sealing, which is considered a poor practice. Farmers in groups 4 and 5 mostly reported using double-sided plastic films (84.4 and 85.7%, respectively; $P < 0.001$). Snell et al. (2003) reported the effects of color on the temperature of the film surfaces. They determined that during the morning hours, temperature peaks were up to 16°C higher for black film compared with white film. The quality of the film used in sealing horizontal silos is a key factor in limiting silage losses, especially in the peripheral area of the mass (Bernardes et al., 2012b).

The majority (91.2%) of farmers used some material to cover the plastic film after sealing the silo. Of these, 69.2% used soil (Table 3). The other respondents used tires (5.8%) or a combination of soil and tires (8.1%). The farmers in groups 1 and 2 used soil ($P = 0.01$) to protect the plastic after sealing (74.1 and 83.3%, respectively). Farmers from groups 1 and 4 mostly used no material to protect the plastic film. Covering the plastic film decreases losses and better preserves the nutritional quality of the silage because the coverage is more effective at controlling the heating of the silage and delays the onset of aerobic deterioration in the upper layer of the silo (Amaral et al., 2010). This strategy also protects the plastic film from solar radiation and climatic conditions, allowing for less degradation of the coverage, particularly in tropical environments. Although effective, protecting the plastic film is sometimes very laborious, given the size of the silos and the amount of silage produced (Muck et al., 2003), and in this case, the quality of the film is indispensable.

Unloading and Face Management

Practices related to the feed-out phase are reported in Table 3. Of all of the respondents, 85.5% removed silage manually (i.e., without the use of machinery). Aside from the harvesting step, the lack of equipment is also reflected in the step of silage utilization. Adesogan (2009) reported that in tropical countries, the low nutritional value of forages, attack of pests and diseases, and climatic conditions affect farmers of both low and high economic power; however, economic and infrastructure barriers mainly affect those of low economic power. In fact, all farmers in groups 1 and 2 removed silage from the silo manually ($P < 0.01$). Conversely, in group 5, almost half (44.9%) used machines ($P < 0.001$). In groups 3 and 4, the majority ($P < 0.001$) removed silage from the silo manually (71.8 and 93.3%, respectively). An advantage of mechanical unloading is that silage removed from the face is deposited into a feed wagon. The forage may then be mixed with other ingredients and delivered in the feed bunk. When machines are used, unloading can be done by frontload bucket tractors or by rotating scrapers. Silage scrapers leave a smooth face, whereas unloading with frontload buckets results in an uneven face with cracks through which air may penetrate; hence, frontload buckets must be avoided (Holmes and Bolsen, 2009).

With respect to the width (on a percentage basis) of the face that is removed from the silo daily, 29.2% of the farmers reported removing silage from the entire face of the silo. The other farmers removed silage from the face heterogeneously, whereas 19.6% removed silage from three-fourths of the face, and 51.2% from half or less (Table 3). Heterogeneously removing silage is reflective of poor silo design (oversized) in relation to the number of animals to be fed. One method to reduce DM losses in the silage removal step is to have an adequate feed-out rate (>30 cm/d) and remove it in its entirety (Mahanna and Chase, 2003). Of the groups of farmers evaluated, groups 1 and 2 removed less ($P < 0.001$) than 100% of the face (15.5 and 12.5%, respectively); the group 5 farmers had greater concern ($P < 0.001$) about this type of practice (44.9%). These results demonstrated that small farmers had greater difficulty in scaling their silos. Several studies (Ashbell et al., 2001; Reiber et al., 2009) have shown that the silage bag is an interesting tool to store feed for small properties located in tropical areas because it is low cost and easy to use. Thus, this technology could be transferred to small farmers in Brazil to improve silage making.

A total of 88.8% of the farmers said they did not discard silage with a deteriorated appearance before providing it to the animals (Table 3). We observed no difference in this practice among all groups ($P = 0.89$). Several studies in cattle (Wichert et al., 1998; Whitlock et al., 2000) and goats (Gerlach et al., 2013) demonstrated that the offer of deteriorated silage, even in small quantities, has a strong negative effect on the animals' intake and the nutritional value of the diet. Moreover, the consumption of spoiled silage can cause negative health consequences (Lindgren et al., 2002) and can contaminate animal products, such as milk and cheese (Vissers et al., 2007; Tabacco et al., 2009).

Barriers Reported by the Farmers

At the end of the questionnaire, farmers were asked about the main barriers or constraints they faced regarding the production and utilization of silages. Several aspects were reported, but 3 had higher frequency: climatic factors, manpower, and equipment. According to the farmers, climatic variations between years or within a year or both have led to certain difficulties, especially in crop management and harvest. Farmers reported the lack of manpower for any type of service or the lack of qualified manpower for certain operations. However, the greatest obstacle was the lack of equipment, especially for the harvest. Because many farmers rely on outsourced services, municipalities, and cooperatives, the crop is not always harvested, chopped, transported, and packed properly. When reporting on the outsourcing of operations, farmers noted the low quality of services as being the main problem, because activities are often rushed and service providers do not properly regulate their equipment. Input costs and the lack of credit were other aspects frequently mentioned by participants. Of the stages that make up the production process, harvest and compaction were those given greater prominence (i.e., when the main problems are encountered). This scenario may be derived from the lack of equipment, as was previously mentioned. The poor quality of the plastic films was the obstacle most indicated when referring to the sealing step. Other barriers cited by participants were the lack of knowledge of the technique, soil type of the property (low fertility or mountainous terrain), and few corn hybrid options exclusive for silage production because the market in Brazil is limited to hybrids that have grains with soft texture [i.e., hard texture grains (flint) predominate].

CONCLUSIONS

This study identified several specific and potential limitations that will need to be overcome to improve the production and utilization of silage on dairy farms in Brazil. The following priorities should be considered for the benefit of the dairy industry: (1) develop appropriate equipment for Brazilian production and utilization of silage to overcome the barriers, which include the lack of equipment and poor qualifications of the workforce; (2) create lines of credit and stimulate the formation of cooperatives to increase the purchasing power of farmers; and (3) create programs to increase the knowledge of farmers and extension workers in relation to important stages of silage production and utilization, including sharpening the harvester knives, the use of high-quality plastic films for sealing the silage mass, designing silos according to the number of livestock, and disposal of deteriorated silage before it is used in livestock feed.

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