DOI: 10.5433/1679-0359.2019v40n5Supl1p2375

Nutritional and morphostructural characterization of pre-dried winter grass silage

Caracterização morfoestrutural e valor nutritivo de silagem pré-secada de culturas de inverno

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Abstract

The aim was to evaluate the productive quality and fermentative as like the nutritional parameters of winter grass silage in the vegetative and reproductive stages in two consecutive crop years. The experiment was carried out at Universidade Tecnológica Federal do Paraná, Campus Dois Vizinhos, Brazil, from April 2012 to December 2013. The experimental field had a 560 m^2 area; it comprised 32 plots of 16 m^2 each, with a space of 0.5 m between blocks. Four winter grass species were used, including *Avena sativa* L. 'IPR 126' (white oat), *Avena strigosa* Schreb. 'IAPAR 61' (lopsided oat), *Lolium multiflorum* Lam. 'Barjumbo' (ryegrass), and *Secale cereale* L. 'Temprano' (rye), being evaluated through silage making in two phenological stages, vegetative and reproductive. The experimental design was randomized block in a bifactorial scheme (cultivar and phenological phase of pasture). The experimental materials were ensiled in polyvinyl chloride (PVC) microsiles, with four replicates per treatment. Pre-drying and ensiling allowed the preservation of material quality. The highest yields of dry matter per hectare were obtained in the reproductive stage; however, the nutritive content at this stage was relatively lower when compared with vegetative. The rye presented relatively less variation of the nutritional composition between the studied phenological stages. The ash content of the forage influenced the pH of the silage, and the highest pH was verified at the vegetative stage. Even with pre-dehydration, the vegetative stage presented a greater loss of effluents than the reproductive stage.
Key words: *Avena sativa*. *Avena strigosa*. *Lolium multiflorum*. *Secale cereale*. silage. Phenological stage.

Resumo

O objetivo foi avaliar a qualidade produtiva, parâmetros fermentativos e nutricionais da silagem das gramíneas temperadas nos estágios vegetativo e reprodutivo em dois anos consecutivos de cultivo. O trabalho foi conduzido na Universidade Tecnológica Federal do Paraná, Campus Dois Vizinhos - PR de abril de 2012 a dezembro de 2013. A área experimental possuía 560 m², divididos em 32 parcelas de 16 m² cada, com 0,5 m de espaçamento entre blocos. As gramíneas avaliadas foram: Aveia Branca cv.

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Received: Apr. 4, 2018 - Approved: June, 26, 2019

IPR 126 (*Avena sativa* L.), Aveia Preta cv. IAPAR 61 (*Avena strigosa* Schreb.), Azevém cv. Barjumbo (*Lolium multiflorum* Lam.) e Centeio cv. Temprano (*Secale cereale* L.), através da confecção de silagem pré-secada em dois estádios: vegetativo e reprodutivo. O delineamento experimental utilizado foi blocos ao acaso em esquema fatorial, avaliando o fator cultivar e o fator estádio fenológico das gramíneas. Foram avaliadas a qualidade nutricional e parâmetros fermentativos da silagem, assim como seu respectivo estádio fenológico. As forrageiras foram ensiladas em microssilos experimentais de PVC, com 4 repetições por tratamento. A pré-secagem e a ensilagem possibilitaram a conservação e qualidade do material. As maiores produções de matéria seca por hectare foram obtidas na fase reprodutiva, no entanto, a composição nutricional nesta fase apresentou teores inferiores comparados ao da fase vegetativa. O centeio apresentou menor variação da composição nutricional entre os estádios fenológicos estudados. O conteúdo mineral da forrageira influencia no pH da silagem, sendo que pH mais elevado é verificado no estádio vegetativo. Mesmo com a pré-secagem, o estádio vegetativo apresenta maior perda por efluentes quando comparada ao estádio reprodutivo.

Palavras-chave: *Avena sativa*. *Avena strigosa*. *Lolium multiflorum*. *Secale cereale*. Ensilagem. Ciclo reprodutivo.

Introduction

Seasonality in pasture animal production systems has encouraged technicians and researchers to use different forage management techniques. Silage production is a tactic widely used as a supplement during forage deficit periods. Initially described as a possibility of forage conservation for use in times of scarcity, it is now a part of the food base of more modern herds, being used continuously (FLUCK et al., 2018a).

Maize and sorghum are the main crops used for silage production in Brazil. However, the use of other fodder materials with a superior nutritive content has been explored. The use of cold-season grasses, such as ryegrass, oats, and rye, for silage production is a viable alternative during forage shortage periods (FEROLLA et al., 2007). These grass varieties show high animal acceptability, palatability, rich protein contents, and high versatility, and can be supplied in their *in natura* form or as silage and hay.

In times of high demand of livestock, much attention has been focused on the production of pre-dried silage (ZAMARCHI et al., 2014). Owing to the high nutritional quality and ease of production of pre-dried silage, a wide range of materials are ensiled. However, the main justification for the wide diffusion and viability of this technique in comparison to the haymaking process is the shorter exposure time of the material to the field, avoiding losses caused by rainfall and low temperatures, which occur more frequently in the winter period and depreciation of material quality as well as the cost of machinery (PEREIRA; REIS, 2001).

The factors that determine the quality of silage are the nutritional value and green matter production of forage (FONTANELI et al., 2012), having a direct influence on the compaction and sizing of the silo. In pastures with high moisture content, low fermentation at high pH can affect the quality of the silage, causing losses, low palatability, and digestibility of the silage material. Ensiling these winter crops without prior drying causes increased nutrient outflow and loss of digestible nutrients.

Another feature that directly affects the quality of silage is the development cycle of the concerned plant species. The advancement of the phenological stage can negatively influence the leaf:stem ratio of plants, with a consequent decrease in their nutritional quality. Usually, when progressing through a phenological stage, plants present a drop in the content of potentially digestible nutrients (PEREIRA; REIS, 2001). In view of the above information, the aim was to evaluate the productive quality, fermentative pH, and effluent losses, as well as nutritional parameters of the silage of temperate grasses, including white oats, lopsided oats, ryegrass, and rye, in their vegetative and reproductive stages in two consecutive crop years.

Material and Methods

The work was conducted between April 2012 and December 2013 in an experimental area of the Research Unit of Annual Cultures of the Universidade Tecnológica Federal do Paraná (UTFPR), Câmpus Dois Vizinhos, a municipality located in the southwest region of the State of Paraná in the Third Planalto Paranaense region. The climate of this region was classified as subtropical humid mesotherm (Cfa), according to the classification of Köppen, and the soil was classified as dystrophic Red Latosol (BHERING et al., 2008). During the experimental period, the monthly rainfall varied from 89.8 to 535.6 mm, the minimum temperature was −1.8 °C, and the maximum temperature was 33 °C, averaging between 15.6 and 19.8 °C. This data was collected in an automatic station of INMET, located at Câmpus, with a timetable published by the Group of Studies in Biometeorology (GEBIOMET, 2016) during the period of planting and cultivation of the evaluated fodder.

Two years of cultivation were evaluated. In both years, the following grass species were evaluated in the experiment: *Avena sativa* L. ‘IPR 126’ (white oats), *Avena strigosa* Schreb. ‘IAPAR 61’ (lopsided oats), *Lolium multiflorum* Lam. ‘Barjumbo’ and *Secale cereale* L.‘Temprano’ (rye). The experimental design was a randomized block design, with four replications, arranged in a bifactorial scheme, evaluating the qualitative and quantitative differences between the cultivars and phenological stages of the studied grass species. In the vegetative stage, the cuts were performed when the plants were in full tillering stage, with emergence of new tillers, presenting high ratio of leaves. In the reproductive stage, the cuts were performed at the beginning of flowering.

The experimental area was 560 m², divided into 32 plots of 16 m² each, with a spacing of 0.5 m between plots. Soil preparation was carried out in a conventional way under the presence of black mucuna (*Mucuna aterrina*) from previous years. In the first year, correction fertilization was carried out, using 288 kg ha^{-1} of triple superphosphate, 80 kg ha^{-1} of potassium chloride, and 144 kg of N, according to the soil analysis and recommendation for cold-season species (CQFS, 2004). In the second year, NPK base fertilization and N applications were performed according to the dosage recommendations from the production expectation of winter forage crops (CQFS, 2004). Seeds were harvested at the viable pure seed densities of 100, 50, 25, and 60 kg ha^{-1} for white oat, lopsided oat, ryegrass, and rye, respectively, with 30% seeds added to compensate for the losses due to implantation methods.

The standardization cut was performed when the plants reached an average height of 25 cm. Subsequently, when they reached a light interception of approximately 95%, the cutting and ensiling of the vegetative-stage plots was carried out. In the reproductive phase, the ensiling was carried out when the grasses started flowering. The cuts were performed on different dates, according to the plant’s reproductive development. The residue height was determined in relation to the structure of the plants, being 10 cm of the soil for lopsided and white oats and 7 cm for ryegrass and rye.

Luminous interception (LI) and leaf area index (LAI) were evaluated using the SunScan apparatus (SunScan Canopy Analysis System - Delta-T Devices Ltda, Cambridge, United Kingdom). For the readings of LI and LAI, direct sunlight was sampled on the surface of the forage sward and close to the soil. Four distinct points were evaluated within 16 m^2 of each plot in order to reduce sampling errors. The schedules were prioritized around midday in order to better capture the solar incidence. These procedures were performed for each plot, regardless of, taking care of each start of the work in a plot, to intercept the direct insolation. LI was estimated as the percentage of light disappearance in the canopy (relationship between the light captured on top of the canopy and sward). Before each cut, two samples were collected in the plots, using a 0.25 m² square, with samples for structural separation (leaves and stems) and forage mass. Afterwards, these samples were sent to a forced circulation air oven at 55 ºC for 72 h. Thus, the forage mass was estimated (kg ha^{-1}), together with the proportion of leaves and stems.

After harvesting, the biomass was left in the field, with stirring every hour, remaining from six to eight hours in this place, until approximately 35% of dry matter, with monitoring of the moisture of the material according to Souza et al. (2002). Thereafter, the material was chopped with 5 cm particle stationary chopper and compacted in 500 cm^3 experimental PVC microsiles with an approximate density of 650 kg m^{-3} (ANDRIGUETTO et al., 2002). To quantify losses by effluents, 200 g of oven-dried sand (at 105 °C for 4 h) was packed in TNT bags, which were added to the bottom of the silo, avoiding direct contact of the silage and sand.

Immediately after the silos were opened, the silage samples were taken for determining their pH values, according to the method described by Detmann et al. (2012), where 9 g of samples were weighed and submerged for 30 min in 60 ml of distilled water. Three consecutive pH readings were taken with the help of a digital potentiometer. Effluent losses were estimated by the equations described by Zanine and Macedo Junior (2006). Chemical analyzes were performed on the silage samples of microsiles and ryegrass, cut in an area of 0.25 m^2 in the field. For the determination of pre-dried matter (PDM), the samples were heated in a forced-circulation oven at 55 °C for 72 h. Subsequently, the samples were milled in Wiley-type mills using a 1-mm sieve screen for chemical analysis. Thus, were analyzed dry matter (DM) by drying at 105 °C for 24 h, Method 967.03 (AOAC, 1998), ash by performing combustion at 600 ° C for 4 h, and organic matter (OM) by using equation 100-ash, Method 942.05 (AOAC, 1998). The crude protein (CP) levels were determined by the Kjeldahl method, Method 984.13 (AOAC, 1997). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were estimated using the Ankom Fyber Analyzer A2000®; alpha-amylase (MERTENS, 2002) was included in the analysis of NDF.

Data were submitted to the analysis of variance through a general linear model (GLM) procedure (SAS, 2013), using the following model:

$$Yijkl=\mu+\alpha i+bj+ek+al+ \alpha eik+\varepsilon ijkl$$

where μ = mean of observations; αi = Effect of i-th treatment; bj = effect of the j-th block; ek = Effect of k-th stage; al = effect of the 1st-nth year; αeij = effect of interaction between treatment factors; εijkl = Error.

With a significant difference (P = 0.05), the means of the treatment and phenological stage were compared by the Tukey test. In case of the interaction of treatment factors, the means were compared by a T-test, with the same level of significance, in addition to Pearson's correlation test among the evaluated components.

Results and Discussion

The rye and ryegrass presented higher LAI values than the other grass species studied (Table 1), and it could be observed that the LI values showed numerical oscillation according to the LAI variation. A value of LAI indicates growth rate, besides favoring the dehydration of the harvested material for hay or pre-drying. However, it reduces the soil moisture losses due to evaporation by presenting a greater soil cover. Brougham (1956), working on different defoliation intensities in ryegrass, reported that the LI values lower than 95% and the LAI values ranging from 3.5 to 5.0 are critical in the development of temperate climate grasses. However, it can be affirmed that a pasture undergoes changes in its structure as the development cycle progresses, exhibiting a greater proportion of leaves, related to higher LAI values, in the vegetative stage and a marked decrease of this structure upon reaching the reproductive stage (AGUINAGA et al., 2008).

Table 1. Structural characteristics of winter grasses in two phenological stages. Dois Vizinhos, PR, 2012; 2013.

Grass	Phenological stage[2]	LAI	LI[1]	Leaves[1§]	Stems[1§]	Forage mass[1]
Lopsided oat	V	7.18±0.66	97.4	56.0	42.8	2834.67
	R	6.32±0.76	98.4	38.61	38.74	7010.33
White oat	V	6.18±1.10	97.0	68.01	29.89	2765.06
	R	6.83±1.12	97.1	37.06	42.22	5640.29
Rye	V	7.8±0.68	98.7	66.12	33.88	1999.6
	R	7.56±0.81	98.7	52.19	35.67	4050.13
Ryegrass	V	7.33±1.25	98.7	69.14	27.13	1654.77
	R	7.96±0.91	98.4	48.8	33.11	4070.4
Standard error		0.91	-	-	-	-
$P \leq 0.05$		*; ns;ns	-	-	-	-

LAI: Leaf Area Index; LI:% Luminous Interceptation; Forage Mass: kg MS ha^{-1}; [1] Descriptive data; §:Contribuition on forage mass in percent; ± Standard Deviation; Two-year growing averages; [2]Phenological Stage: V: Vegetative; R: Reprodutive; $P \leq 0.05$: F test with α=0.05, for the factors grass, stage, and interaction between grass*stage; *:Significative; ns: Not Significative.

The pre-drying aided in increasing the DM contents to the values close to those desired (Table 2); however, a staining effect was observed in the contents of this variable. Vanbelle et al. (1983) commented that the pre-drying technique is used to cut the forage, following the pre-wilting treatment, until the material reaches 30 to 45% dry mass. In order for the fermentation process of the silage to take place within the indicated time, it is necessary to take into account the DM content of a forage species before selecting it for use. This determines whether the techniques that aim to minimize nutrient leaching losses, such as pre-drying and use of additives, are required. In this study, all treatments presented satisfactory DM contents, contributing to rapid oxygen uptake after micro-silage sealing, a determinant factor for the initiation of silage fermentation (McDONALD, 1981).

Table 2. Chemical composition of pre-ensiled of winter grasses in two different phenological stages. Dois Vizinhos, PR, 2012 e 2013.

Grass	Phenological stage[2]	Chemical composition§					
		DM§§	OM	Ash	CP	NDF	ADF
Lopsided oat	V	352.2±4.58	893.9±10.4	106.1±10.4	261.4±34.8	524.6±25.3	250.0±22.6
	R	375.8±2.72	927.3± 10.9	72.7±10.9	195.0±24.5	622.4±32.7	337.1±45.2
White oat	V	348.1±3.7	900.0±17.7	100.0±17.7	233.7±16.3	539.1±57.4	266.5±42.0
	R	371.2±2.79	930.4±8.30	69.6±8.30	187.9±30.5	610.2±24.1	324.8±18.7
Rye	V	351.9±7.8	892.0±18.7	108.0±18.7	265.1±12.5	523.5±35.1	244.5±10.4
	R	374.0±2.5	924.7±4.03	78.1±4.03	223.8±20.8	583.3±61.5	278.7±19.6
Ryegrass	V	349.6±8.7	884.7±19.2	115.3±19.2	252.8±38.1	522.3±23.8	218.5±13.5
	R	373.7±3.9	919.7±18.9	80.3±18.9	205.9±19.6	559.5±28.9	258.9±32.6
Standard Error		5.14	18.14	13.34	16.56	39.02	28.25
$P \leq 0.05$		ns;*;ns	ns;*;ns	ns;*;ns	*;*;ns	*;*;ns	*;*;*

§ Values express in g kg^{-1} of Dry Matter; §§: Values express in g kg^{-1} of Natural Matter; DM: Dry Matter; OM: Organic matter; CP: Crude Protein; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber; ± Standard Deviation; Two-year growing averages; [2]Phenological Stage: V: Vegetative; R: Reprodutive; $P \leq 0.05$: F test with α=0.05, for the factors grass, stage, and interaction between grass*stage; *:Significative; ns: Not Significative.

The ash and OM contents were influenced only by the stage of development, the upper ash being in the vegetative stage and the OM in the reproductive stage, indicating a direct relationship between the ash and OM contents and thickness of a plant cell wall, since, young plants present cells with higher soluble content and less thick walls (FLUCK et al., 2018b). With the advancement of the development cycle, a plant gradually changes the type of accumulated tissues, exhibiting an increase in support tissues (VAN SOEST, 1994), such as stems, in this case, reflecting an increase in fibrous fractions.

The CP content presented a significant difference, both among cultivars and phenological stages. It was noticed that in all cuttings, the rye stood out in relation to the CP content. This was attributed mainly to its high nutritional value derived from tender leaves and rapid reestablishment of the crop after cutting, with a relatively long development cycle (FONTANELI et al., 2009). Furthermore, the decrease in CP content with the evolution of a phenological stage was low, varying by approximately 6 percentage points for the cultivars studied. Rodrigues et al. (2002), working with different forage species in the lowlands, recorded the average CP values ranging from 16% to 19.0%. In addition, they found differences in the CP content in relation to the phenological stage, as indicated by a decrease of approximately 3 percentage points during progression to the reproductive stage.

A gradual increase in the contents of NDF and ADF was observed with the interaction between treatment factors. With the advancement of the phenological stage, the NDF level was higher for all grass species. This result can be justified because, at this stage, grasses generally have a lower leaf/stem ratio, increased fibrous content, and decreased soluble content (VAN SOEST, 1994; COSTA et al., 2018). In addition, plant and botanical changes, such as the elongation of internodes and emergence of inflorescences, occur in a pasture, resulting in a decrease in its nutritive value of pastures (SKONIESKI et al., 2011; COSTA et al., 2018).

In the silage, the DM contents presented variation only in the phenological stage factor. The contents of OM and ash presented the same behavior as in the pre-silage material. These variables are extremely important in silage because they are directly related to the silage quality and the material's buffering power. The mineral content might increase the ability of the material to withstand pH variation (PLAYNE; McDONALD, 1966)

The CP losses in the silage and pre-ensiled material were not evaluated. It is worth noting that regardless of the silage process efficiency, the maximum obtainable output of the silage process is the maintenance of the nutritional value of the silage material, and if it is done in an erroneous way, the quality can easily be impaired (JOBIM et al., 2007). The protein levels decreased with the progress of the development stage in all grass species, being observed significant difference in the protein levels between the grass species. Meinerz et al. (2011), evaluating the silage of different winter cereals, also found a difference in the protein levels between the cultivars evaluated. Boin et al. (2005), when searching for silages from white oats, found that the protein levels varied according to the stage of development, with the CP content decreasing at the reproductive stage. However, Fluck et al. (2018b) reported a decrease of approximately 64% in the CP content of the silage when the plants progressed from the vegetative to the flowering stage.

The NDF content of the silage was numerically lower than that of the fresh silage material (Table 2 and 3). This difference occurs through the pruning and fermentation processes, breaking the cell wall, leaving the material with the greater surface exposed, and thus, contributing to the action of microorganisms in the fiber. This behavior is contrary to the expected, since the losses of non-structural compounds in the fermentation process usually increase the fiber fraction content in the forage. However, the disappearance of this percentage of NDF indicates that the hemicellulose fraction might have been solubilized.

Table 3. Chemical composition, pH and effluent losses of silage of winter grasses in two different phenological stages. Dois Vizinhos, PR, 2012 e 2013.

Grass	Phenological stage[1]	Chemical composition §							
		DM§§	OM	Ash	CP	NDF	ADF	pH	Effluents Losses§§
Lopsided oat	V	350.5±23.4	903.0±20.9	97.00±20.9	257.6±20.9	429.7±12.8	270.9±42.6	5.4±0.74	62.7±2.6
	R	369.3±19.1	926.7±6.6	73.30±6.6	168.7±40.2	588.6±58.9	347.4±31.0	5.04±0.25	31.6±1.6
White oat	V	346.3±10.6	888.8±19.4	111.2±19.4	239.6±15.1	467.0±42.2	284.3±45.3	5.62±0.37	51.3±2.4
	R	351.2±31.9	830.3±17.3	79.40±17.3	180.8±23.0	547.4±35.3	339.3±15.4	5.22±0.58	37.4±2.6
Rye	V	353.6±22.7	895.3±9.90	104.7±9.90	252.5±32.7	417.0±32.8	244.5±16.5	5.6±0.31	41.6±8.40
	R	359.0±26.5	919.0±8.50	81.00±8.5-	213.5±27.9	510.0±35.5	288.2±11.3	5.45±0.52	36.5±1.5
Ryegrass	V	348.3±16.9	889.3±10.2	110.7±10.2	233.4±14.4	416.4±23.9	224.1±11.0	5.59±0.26	54.9±1.3
	R	359.1±18.7	900.2±11.4	99.80±11.4	190.6±21.5	519.2±31.8	282.3±25.5	5.01±0.53	35.1±2.1
Standard error		21.19	13.63	13.63	25.07	36.57	24.84	0.49	18.4
P ≤0.05		ns;*;ns	*;*;ns	*;*;ns	*;*;*	*;*;ns	*;*;*	ns;*;ns	ns;*;ns

§ Values express in g kg^{-1} of Dry Matter; §§: Values express in g kg^{-1} of Natural Matter; DM: Dry Matter; OM: Organic matter; CP: Crude Protein; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber; ± Standard Deviation; Two-year growing averages; [1]Phenological Stage: V: Vegetative; R: Reprodutive; P ≤0.05: F test with α=0.05, for the factors grass, stage, and interaction between grass*stage; *:Significative; ns: Not Significative.

In both stages, the lowest levels of NDF were found in ryegrass and rye. Among the two stages, the NDF content increased according to the progression of the stages, being the highest in the reproductive stage, when the quality of the forage diminishes drastically (PARIS et al., 2015). An increase in the NDF content was found to be the primary factor for the decline in the nutritional quality of a forage species (KOZLOSKI et al., 2005). In addition, it was found that the NDF content presented a negative correlation with the mineral matter and protein contents (CP: −0.71, P = 0.0001; Ash: −0.54, P = 0.0001).

For the ADF content, significant differences were observed with the interaction between the two factors studied. As for the NDF content, the lowest values were observed for ryegrass silage and rye silage in both stages, being superior at the reproductive stage compared to the vegetative stage. In agreement with our findings, Lopes et al. (2008), evaluating oat silages at different cutting ages, observed an increase in the levels of ADF with an increase in the cutting age.

Mesquita and Neres (2008) reported that as a consequence of the fast development of grasses, their cellular nutrient content decreased with increasing age, leading to an accumulation of low-digestibility nutrients because of the increase in the content of cell wall compounds, such as NDF and ADF, to the detriment of CP. However, despite of the high fibrous contents found in the reproductive stage; Paiva and Oliveira (2006) reported that the high leaf-to-stem ratio and high composition of soluble carbohydrates, which act as substrates for fermentation and consequent pH reduction, favor more efficient degradation of the fiber, providing a high-quality silage for animals, in relation to the widely used fodder materials.

No significant difference in pH was observed between grasses (P>0.05), only between stages, being higher in the vegetative than in the reproductive stage (Table 3). The pH values were higher than those found by Meinerz et al. (2011), who evaluated the silage of different dual-purpose temperate grasses and found the pH values ranging between 3.73 and 4.39.

The pH of the silage is directly related to the DM content of the plant at the moment it is ensiled. Owing to the high moisture content in the vegetative stage, temperate grasses must undergo a prior dehydration process to ensure adequate DM contents for proper fermentation of the material, making it difficult to develop aerobic microorganisms, such as *Clostridium ssp.,* that can deteriorate silage (SIQUEIRA et al., 2007; SANTOS et al., 2010; COBLENTZ et al., 2014). Although the pH values recorded in this study were higher than those indicated by some authors (PEREIRA et al., 2007; LIU et al., 2016; RAZMKHAH et al., 2017), who recommended pH variations between 3.5 and 4.5, the DM content of the ensiled material in this study was considered adequate (McDONALD et al., 1991), compensating any problem related to inadequate fermentation, which, in turn, is related to this parameter (pH) that can be considered of little relevance when the contents of pre-ensiled DM are above 35% (FRANÇA et al., 2007).

In general, the critical pH value of silage varies directly with the dry matter content of the ensiled plant; the higher the dry matter content, the higher is the pH value, unless the soluble carbohydrate levels are exceptionally high. Furthermore, as mentioned above, the pH value has a close relationship with the mineral content of the plant, with high contents of mineral matter increasing the resistance of the material to pH oscillation. However, this does not have a great influence on the final quality of the silage, if factors, such as compaction and anaerobiosis, are considered.

The highest losses due to effluents were verified at the vegetative stage, being the observed effects of the stages and grass species evaluated. Rye presented the least amount of effluent loss. Zamarchi et al. (2014) reported that losses might occur during the conservation process because of the intrinsic characteristics of the forage silage, as well as the stage of maturation and chemical composition of the forage species. Corroborating these findings, Santos et al. (2010) showed that these factors can act alone or jointly, reflecting on the fermentative process according to each cultivar. The production of metabolic water in the fermentation process can also occur, especially in the presence of O_2. Thus, even with adequate moisture content, if there is adequate compaction, there might be a loss of nutrients by aerobiosis and leaching with the water synthesized as long as there is O_2 in the medium. However, the losses presented a positive correlation with the protein content (0.67, P = 0.0001) and a negative correlation with the NDF contents (-0.41, P = 0.0009), affirming that higher NDF levels help reduce leaching losses.

Conclusion

The rye presents relatively less variation of the nutritional composition between the studied phenological stages.

The mineral content of the forage influences the pH of the silage, with the highest pH recorded in the vegetative stage.

Even with wilting, the vegetative stage presents greater losses by effluents when compared to the reproductive stage.

Acknowledgements

We thank the Coordination of Superior Level Staff Improvement (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-CAPES) for financial support of this study (finance code 001).

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