Ciência Animal Brasileira

DOI: 10.1590/1809-6891v21e-58129

Nutritional value and digestible dry matter production of oat genotypes for ensiling

Valor nutricional e produção de matéria seca digestível de cultivares de aveia visando à produção de silagem

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Section: Zootecnia

Received
April 15, 2019.
Accepted
September 6, 2019.
Published
June 16, 2020

www.revistas.ufg.br/vet
visit the website to get the how to cite in the article page.

Abstract

This study evaluated dry matter yield and nutritional characteristics of different oat genotypes (*Avena* spp.) for ensiling. Treatments consisted of genotypes of white oat IPR 126 (*Avena sativa*), black oat Cabocla IPR and Agrocoxilha (*Avena strigosa*), and BRS Madrugada and BRS Centauro (*Avena vertis*). Oats were harvested at the phenological stage of milk/dough grain. The design was a completely randomized block scheme, with five treatments and three replications per treatment. The IPR Cabocla genotype showed the highest dry matter content (before and after silo opening) and *in vitro* dry matter digestibility of fresh forage. No differences were observed for *in vitro* dry matter digestibility and dry matter losses among silages. The highest silage digestible dry matter yield (kg ha^{-1}) was observed for the BRS Centauro genotype. Thus, despite the better nutritional quality presented by the IPR Cabocla genotype before ensiling, BRS Centauro genotype presented a higher yield of digestible dry matter per hectare.

Keywords: winter crop; ensiling; *in vitro* dry matter digestibility; dry matter losses

Resumo

Este trabalho teve como objetivo avaliar as características produtivas e nutricionais de diferentes cultivares de aveia (*Avena* spp.),visando à produção de silagem. Os tratamentos foram constituídos dos cultivares de aveia branca IPR 126 (*Avena sativa*), Agrocoxilha, e IPR Cabocla (*Avena strigosa*), bem como das cultivares BRS Madrugada e BRS Centauro (*Avena vertis*). As forragens foram colhidas e ensiladas quando atingiram o estádio fenológico de grão pastoso/farináceo. O delineamento experimental foi em blocos casualizados, com cinco tratamentos e três repetições por tratamento. O cultivar Cabocla apresentou os maiores teores de matéria seca (antes e após a abertura dos silos) e maior digestibilidade *in vitro* da matéria seca no momento de ensilagem. Após a ensilagem não foram observadas diferenças para a digestibilidade *in vitro* e perdas de matéria seca entre os tratamentos. Contudo, após correção dos respectivos valores para perdas de matéria seca na ensilagem e digestibilidade *in vitro* da matéria seca,

observou-se maior produção de matéria seca digestível (kg ha^{-1}) para o cultivar Centauro.
Palavras-chave: cereal de inverno; ensilagem; digestibilidade *in vitro*; perdas de matéria seca.

Introduction

The seasonality of pasture production in Brazil is related mainly to climate factors and species used for foraging, leading to a higher forage yield during the summer season. Thus, the nutritional supplementation of cattle is necessary to preserve the performance levels throughout the year[1]. In addition, many farmers have adopted more intensified productive systems, increasing the need for feed in terms of quantity and quality. In this sense, ensiling becomes an interesting alternative to store feed and maintain its quality. Regardless of the availability of conventional crops for ensiling (e.g., corn, sorghum, and sugar cane), the interest for ensiling winter crops has been increasing. This strategy avoids direct competition for an area with other higher value-added crops, such as soybean or corn, as well as allows using usually idle areas during the winter in Brazil. However, high availability of annual winter crop species (e.g., oat, ryegrass, wheat, and triticale), along with low amount of information about ensiling these crops, makes it difficult to adopt this strategy.

Oat (*Avena* spp.) is one of the most cultivated temperate grass for forage production in Brazil. White oat (*Avena sativa*) has a good dry matter yield, with high leaf participation in forage mass, as well as great grain production, characteristics of interest for ensiling[2]. Black oat (*Avena strigosa*) presents a high tillering capacity, high production of dry matter[3, 4], and resistance to periods of low rainfall and pests. In addition, black oat nutritional quality is satisfactory in relation to animal requirements[5, 6]. In this way, the interest in ensiling winter crops has grown recently, leading to investments in research to obtain new genotypes, with high dry matter yield and adaptation to cultivation under Brazilian conditions. Currently, several oat cultivars have been available to farmers for cultivation, which determines the need for studies for silage production. Thus, the objective of this study was to evaluate the characteristics related to forage production and nutritional quality of different oat cultivars aiming ensiling.

Material and Methods

The experiment was conducted at the Experimental Farm of Iguatemi (23°25' S and 51°57' W) of the State University of Maringá-PR (UEM). Laboratory analyses were performed at the Laboratory of Feed Analysis and Animal Nutrition in the Department of Animal Science of the UEM. Treatments consisted of genotypes of white oat IPR 126 (*Avena sativa*), black oat (*Avena strigosa*) Cabocla IPR and Agrocoxilha, and BRS Madrugada and BRS Centauro (*Avena vertis*). Planting was performed in May 2014. Soil is classified as a sandy textured Red Latosol[7]. Pre-sowing fertilization was equivalent to 180 kg ha^{-1} of the NPK formula 12-17-17 (N, P_2O_5, K_2O), as recommended by CQFS RS/SC[8]. For each genotype, three plots of seven m^2 (1.4 x 5.0 m) were planted with a row spacing of 20 cm. Sowing density for all crops was equivalent to 80 kg of seeds ha^{-1}. Nitrogen fertilization was performed in a single application of urea equivalent to 100 kg of N ha^{-1} at 21 days after plant emergence. Crops were manually harvested at the grain milk/dough stage. Due to differences in the forage development cycle, harvesting occurred from September to October 2014. To calculate forage yield (kg ha^{-1}) within each plot, 10 samples of 1 linear meter were collected using a graded ruler. All forage collected was weighed, and an aliquot (400 g) was taken for dry matter determination in a forced ventilation oven (55 °C for 72 hours) and stored for further analysis.

For ensiling, harvested forages were processed in a stationary chopper with a theoretical particle size of 20 mm. Three experimental silos (vacuum bag; 500 g each) were produced from each plot using a vacuum sealing machine (TecMaq® TM250). Experimental silos were stored out of direct light exposition at room temperature for 120 days. Before opening, the silos were weighed for dry matter loss estimation, as described by Jobim et al.[9]. In addition, representative silage samples were collected for pH[10] and dry matter (DM) measurements (55 °C for 72 h). Dried samples (from crops and silages) were ground in a Willey mill (1-mm sieve) for laboratory analyses. Processed samples (crops and silages) were subjected to the following analysis: moisture (105 °C)[11] (method 967.03); ash[11] (AOAC method 942.05); crude protein[11] (CP, AOAC method 990.03); neutral detergent fiber (NDF)[12] and acid detergent fiber (ADF)[13] and *in vitro* dry matter digestibility (IVDMD), according to Holden[14]. In order to calculate forage digestible DM yield before ensiling (FDY), crop DM yield was multiplied by the *in vitro* DM digestibility for each genotype: FDY (kg ha^{-1}) = Forage DM yield × IVDMD. Regarding silage digestible DM yield (SDY), dry matter losses were considered for each treatment: SDY (kg ha^{-1}) = [Forage DM yield - (Forage DM yield × Silage DM losses)] × IVDMD of silage. The experimental design was totally randomized blocks with five treatments and three replications. All data were submitted to analysis of variance and compared by Tukey's test at 5% significance level by the GLM procedure of the SAS statistical program[15].

Results

The pH values in silages were influenced by DM content at harvesting. The highest pH value was observed in IPR Cabocla silage (black oat), differing only from the pH observed in the Madrugada genotype silage (Figure 1). No differences were observed regarding DM loss in the silages.

Crops and silages presented different DM contents, ranging from 41.04% to 57.28%, besides of the same developmental stage at harvesting (milky/dough grain) (Table 1). The IPR Cabocla presented the highest DM value for both crop and silage ($p < 0.05$).

Regarding the chemical composition of crops, the Centauro genotype had the lowest ash content ($p<0.05$). The lowest NDF values were found in BRS Madrugada, IPR Cabocla, and Agrocoxilha genotypes, whereas BRS Madrugada, IPR Cabocla, and BRS Centauro genotypes had the lowest values of ADF content. At harvest, forages did not present significant differences regarding CP content. Silages from IPR Cabocla presented the higher ash content, followed by the IPR 126 genotype. The silage from Agrocoxilha genotype had the highest NDF value, whereas the highest ADF content was found for IPR Cabocla. The CP values changed due to ensiling and silages from IPR Cabocla and IPR 126 genotypes presented the lowest CP values.

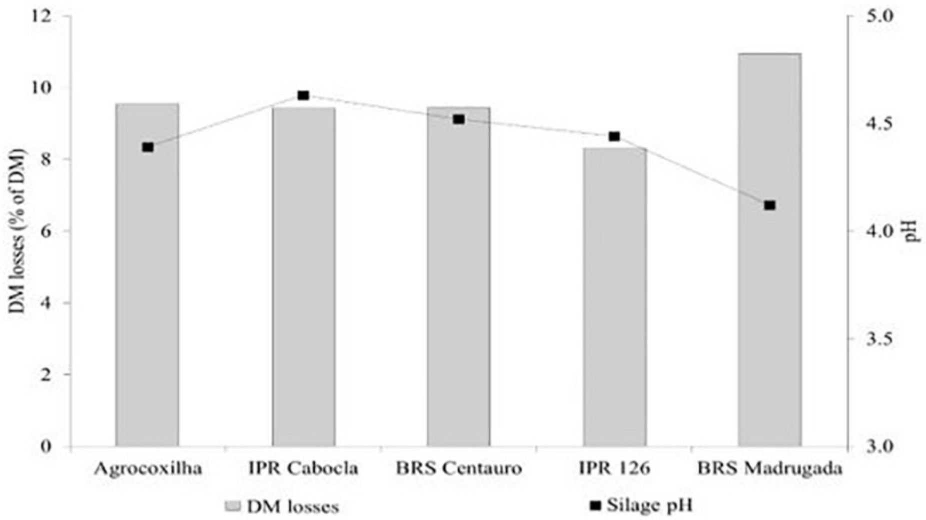

Figure 1. Dry matter losses during storage (SEM =1.02) and pH at opened silos (SEM = 0.082). Means identified by distinct letters are different by Tukey's test 5%.

Table 1. Chemical composition of forages before and after ensiling

Oat	Crop					Silage				
	DM[1]	Ash[2]	NDF[2]	ADF[2]	CP[2]	DM[1]	Ash[2]	NDF[2]	ADF[2]	CP[2]
Agrocoxilha	43.3^{b}	7.65^{ab}	68.5^{bc}	44.8^{ab}	11.9	46.3^{b}	8.33^{bc}	72.1^{a}	40.2^{c}	11.7^{a}
IPR Cabocla	57.2^{a}	8.83^{a}	68.1^{bc}	38.7^{c}	12.0	56.9^{a}	9.58^{a}	64.6^{c}	43.6^{a}	10.1^{bc}
BRS Centauro	51.1^{ab}	6.25^{c}	70.3^{ab}	42.9^{bc}	10.5	49.8^{ab}	7.10^{d}	68.3^{b}	43.2^{ab}	11.4^{a}
IPR 126	42.2^{b}	8.31^{ab}	71.9^{a}	46.4^{a}	11.0	46.9^{b}	9.13^{ab}	64.3^{c}	41.0^{bc}	9.53^{c}
BRS Madrugada	41.0^{b}	7.19^{bc}	67.4^{c}	41.2^{c}	10.5	47.6^{b}	8.01^{cd}	69.8^{ab}	41.3^{abc}	10.9^{ab}
Mean	46.9	7.65	69.2	42.8	11.2	49.5	8.45	67.8	41.9	10.7
SEM	1.92	0.26	1.07	0.85	0.17	1.29	0.25	0.85	0.40	0.24
p-Value	**	*	**	***	ns	*	***	***	**	**

[1] % as fed; [2] % DM. [abcd] Means followed by distinct letters within the same column are different by Tukey's test (*P < 0,05; **P < 0,001; ***P < 0,0001). SEM – standard error of the mean. ns – non significant.

In vitro DM digestibility was different among forages before ensiling. As observed in Figure 2, IPR Cabocla presented higher *in vitro* DM digestibility (p <0.05). However, after ensiling, this difference was suppressed.

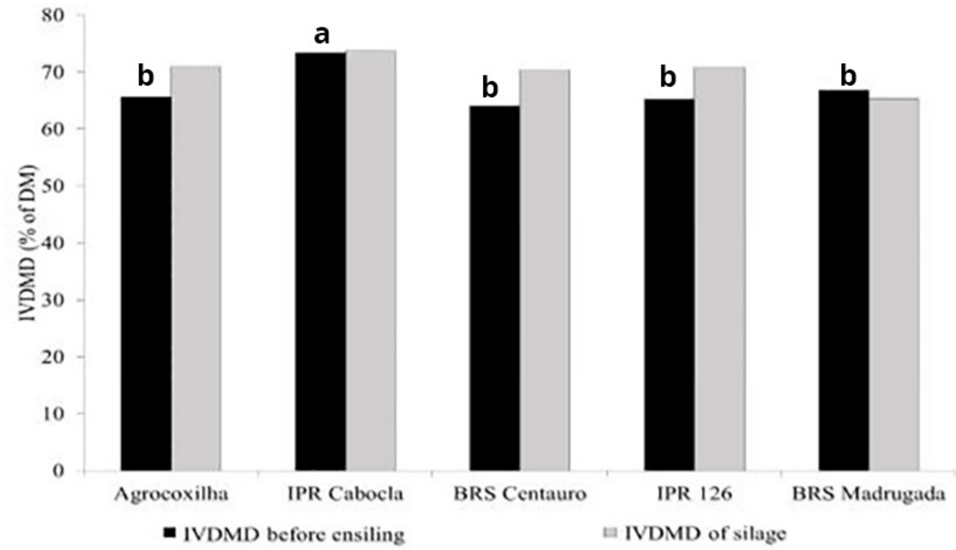

Figure 2. *In vitro* dry matter digestibility (IVDMD) of oat genotypes before ensiling (SEM = 1.04) and respective silages (SEM = 1.34). Means identified by distinct letters are different by Tukey's test 5%.

The DM yield before ensiling (total DM and digestible DM) was distinct among crops, and the black oat BRS Centauro had the highest yield (Figure 3). The genotypes Cabocla and Madrugada presented intermediate yields (6997 kg ha^{-1} on average), but higher than that of Agrocoxilha and IPR 126 (5215 kg ha^{-1} on average). Regarding silage digestible DM yield, the Centauro genotype remained as the most productive forage.

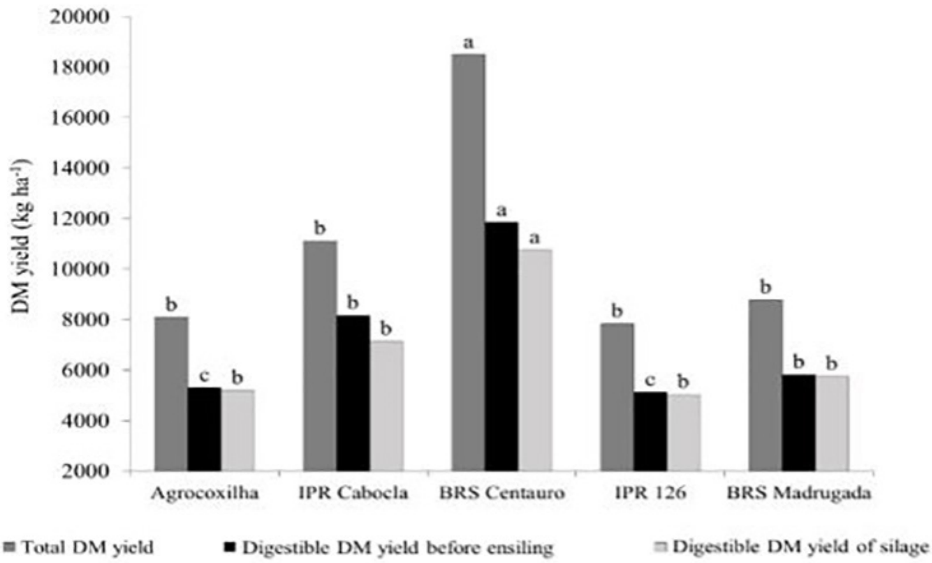

Figure 3. Total dry matter yield (**SEM** = 1168.8) and digestible dry matter yield of oat genotypes before ensiling (**SEM** = 749.4) and the respective silage, corrected for DM losses during storage (**SEM** = 614.0). Means identified by distinct letters are different by Tukey's test 5%.

Discussion

Forage DM content is strictly related to its development stage, normally increasing over time due to the accumulation of lignified tissues and senescent structures, as well as due to the synthesis of starch in grains[3, 16, 17].

Temperate grasses in general present high buffer capacity[2,6] and low soluble sugar content[3,18], increasing the risk of spoilage during fermentation. In this way, DM content at ensiling must range between 30 and 40% to reduce DM losses. Moreover, the adequate DM content associated with a pH below 5 increase conservation efficiency. Thus, the average DM content observed in this trial (above 40%), combined with the low pH (average of 4.39), effectively contributed to silage conservation. The DM losses in this study (average of 9.53%) were lower than that observed by Oliveira et al.[19] evaluating wheat silage with a similar DM content, as observed in this trial.

Ash constituents are not consumed during fermentation, but the consumption of soluble nutrients usually leads to an increase in ash content (dilution effect)[20]. Similar behavior is expected for fibrous compounds since microorganisms in the silage lack enzymes necessary to metabolize plant cell wall constituents[21]. On the other hand, a reduction in NDF content may be linked to hemicellulose hydrolysis in acidic media[22].

The ADF concentration is negatively related to forage digestibility[23] and observed in IVDMD of IPR Cabocla genotype (low ADF and high IVDMD). However, ensiling equalized forage digestibility, probably due to the oxidation of soluble compounds[24]. The CP is one of the most expensive nutrients in ruminant diets; thus, the use of temperate grasses in ruminant diets reduces the need for external protein supplementation. Temperate grasses present higher amounts of the Rubisco enzyme (linked to the photosynthetic metabolism C3), enhancing nitrogen content when compared to C4 grasses[25]. The crops evaluated in this study presented satisfactory CP contents when compared to the observed in other studies evaluating oat silage nutritional quality[15, 26]. The DM yield dictates the amount of roughage available for animal feeding and is directly related to production costs (kg ha^{-1}). However, the ensiling process tends to modify some nutritional characteristics of feed due to the development of microorganisms and soluble substrate consumption. These modifications in composition along with inherent losses should be considered for planning purposes. Thus, an interesting measurement, adopted as a variable in this work, would be evaluating the digestible DM yield (kg ha^{-1}) instead of solely DM yield. As observed in Figure 3, there was a decay in DM yield when considered the IVDMD, as well as DM losses, but it allowed getting a real perception of yield potential for each silage.

Conclusions

Oat cultivars harvested at the milky/dough grain stage presented satisfactory nutritional quality before and after ensiling. No difference regarding *in vitro* dry matter digestibility and dry matter losses was observed among silages. On the other hand, the digestible dry matter yield was distinct among oat genotypes, being a relevant factor in defining the oat to be ensiled according to productive purposes.

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