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Black oat grown with common vetch improves the chemical composition and degradability rate of forage

Fabiellen Cristina Pereira[1*], Luiz Carlos Pinheiro Machado Filho[1], Daniele Cristina da Silva Kazama[1] and Roberto Guimarães Júnior[2]

[1]Laboratório de Etologia Aplicada, Departamento de Zootecnia e Engenharia Rural, Universidade Federal de Santa Catarina, Rodovia Admar Gonzaga, 1346, 88034-000, Florianópolis, Santa Catarina, Brasil. [2]Empresa Brasileira de Pesquisa Agropecuária, Embrapa Cerrados, Brasília, Distrito Federal, Brasil. *Author for correspondence. E-mail: fabiellenpereira@gmail.com

ABSTRACT. This study aimed to evaluate the effect of cultivating a combination of common vetch (*Vicia sativa* L.) with black oats (*Avena strigosa* Schreb.) on the chemical composition of forage and the grazing behavior of heifers. To accomplish this, two paddocks 2500m^2 each from a Voisin Rational Grazing management system were divided into three blocks each and then into thirds (278m^2) characterizing a randomized block design. Three different forage compositions were distributed into these thirds: oats grown alone, vetch grown alone, and oats grown with vetch. Forage samples were collected after 65 days through the square method. Right after collection, three groups of four heifers each grazed the plots for two hours in a 3x3 double Latin Square design for behavioral observation, grazing simulation through the hand-plucking method, and biting rate determination. Forage samples collected either by hand-plucking or the square method, were analyzed for chemical composition and "in vitro" degradability. Statistical analyses were performed using the R package lme4. Data were evaluated with linear mixed-effects models. The inclusion of common vetch significantly increased forage production and oat protein content, but decreased the fiber content, which promoted better "in vitro" degradability. Grazing frequency was higher in pasture where oats were grown with vetch, but the biting rate was similar in all the three forage compositions evaluated. Forage collected by the square method did not differ from forage consumed by the heifers, probably meaning low herbage selectivity by heifers. Furthermore, no interaction of investigated variables occurred between forage compositions and the method of collection. The inclusion of common vetch with black oats increased forage chemical composition, "in vitro" degradability, and forage production, thus having positive effects on the time cows spent grazing.

Keywords: cattle behavior; grazing; sustainability.

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Introduction

Brazil has the largest number of cattle herds in the world, with a worldwide economic impact (Food and Agriculture Organization of the United Nations [FAO], 2019). Brazilian cattle are mostly raised on pasture, which occupies as much as 196 million hectares (ha) (FAO, 2019). Despite the global relevance, Brazilian livestock systems still need to be improved. Overall, these systems can be characterized by the low growth of cattle (Salton et al., 2014), unstable forage productivity based on seasonality (Ferraz & Felicio, 2010), degraded soil, and low nutritional value of forage (Berndt & Tomkins, 2013).

Therefore, increasing cattle growing efficiency requires strategies that also promote low environmental impact (Salton et al., 2014). One readily available and low-cost strategy is the management of pasture, which promotes more resilient and better nutritional forage (Teague, Provenza, Kreuter, Steffens, & Barnes, 2013).

A very common strategy in southern Brazil is growing annual winter plant species over native species that have a low rate of growth during this season (Ferraz & Felicio, 2010). This practice is magnified when different species are mixed, and legumes are included. Legumes promote soil fertility and nutrient cycling that, together, promote the growth of grasses (Martin et al., 2016) and reduce the use of chemical fertilizers (Anjos et al., 2016). Black oats (*Avena strigosa* Schreb.), an annual winter species, and the common vetch (*Vicia sativa* L.), a legume, are commonly used in southern Brazil, and it has been recommended that they be grown together.

Oats provide high digestibility and productivity (Kafilzadeh & Heidary, 2013), whereas high energy and protein are provided from the common vetch (Huang, Gao, Nan, & Zhang, 2017). Those characteristics have been found to increase the nutritional value and degradability of forage, thus improving cattle efficiency (Wanapat, 2000). Notwithstanding, it is essential also to verify how the cattle will accept a new forage composition since they also have food preferences (Benvenutti, Pavetti, Poppi, Gordon, & Cangiano, 2016). Therefore, we aimed to compare oats and vetch grown separately, or the two species grown together, all seeded over the natural pasture and under intensive grazing conditions in order to evaluate chemical composition and the "in vitro" degradability of these plants, as well as heifers' grazing behavior and selectivity on these three forage options.

Material and methods

This study was done between June and August of 2017 at the Voisin's Rational Grazing (VRG) Unit at the Federal University of Santa Catarina (UFSC) Experimental Farm of Ressacada, Florianópolis, Brazil (27°40'25" S; 48°32'30" W). The climate in this region is humid subtropical according to the Köppen climate classification (Alvares et al., 2013), where the annual average rainfall is 1462 millimeters and the average temperature is 20°C. This study was performed in accordance with the Ethics Committee of Animal Use in the UFSC (CEUA) under approved protocol No. 1004100516. The animals are routinely raised on 21 ha of pasture divided into 84 paddocks averaging 2500m^2 under a VRG management system.

Two paddocks were divided into three blocks each characterizing a randomized block design. Blocks were divided into thirds (278 m^2). Three different forage seed compositions were sown by hand into thirds: oats grown alone (100 kg ha^{-1}), vetch grown alone (60 kg ha^{-1}), and oats grown with vetch (80kg ha^{-1} + 40 kg ha^{-1}). These compositions were overseeded, and afterwards, they were stepped on by heifers to guarantee the introduction of the seed into the soil. The pasture was fertilized with poultry manure (1.75 t ha^{-1}).

Approximately 65 days after seeding, the total of the six blocks were used subsequently from block one to block six per day. Five samples of forage were cut into thirds using a 0.5 x 0.5 m^2 measurement at soil level. Every sample was randomly selected by throwing an iron square where it might land. Each sample was weighed to measure forage production and then used as a final sample to determine chemical composition. Samples were weighed and taken to a laboratory, dried at 55ºC for three days, and then weighed and ground to 1 mm in a hammer mill.

To quantify dry matter (DM) and mineral matter (MM) content we used the methodology described by Association of Official Analytical Chemists (AOAC, 1995). For crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF), we used near infrared spectrometry (NIR). The reflectance spectra of samples were collected with a MPA FT-NIR spectrometer (BRUKER OPTIK GmbH, Rudolf Plank Str. 27, D-76275 Ettlingen) in triplicate.

Twelve heifers were selected and separated into three groups according to the hierarchy in the herd to which they belonged, with the average weight of 300 kg. These groups were rotated through a systematic distribution cycle to access the forage sample thirds right after forage samples collection. Each day, they went through a different block and third of pasture based on a 3x3 double Latin square design, double blocking the animal and the aleatory area of variance. The groups of heifers were observed for two consecutive hours (from 8:00 to 10:00) each experimental day.

Observers were trained and were located 15 meters from the animals to avoid disturbing them (Machado Filho, D'Ávila, Kazama, Bento & Kuhnen, 2014). A sample scan from each animal was taken every five minutes (Altmann, 1974). The following behaviors were recorded on a spreadsheet: grazing, ruminating, idling, and any other behaviors (Coimbra, Machado Filho & Hötzel, 2012). Additionally, we sampled the biting rate of each animal five times each hour for 30 seconds each (Machado Filho et al., 2014). The average of these 5 records was used as the biting rate for each animal from which we made an average per group.

Grazing simulation was also performed in accordance with the hand-plucking technique (Wallis de Vries, 1995). Three samples were collected from each animal per day in order to make a representative sample from each group per block per forage category. Samples collected by hand-plucking were submitted to chemical composition analysis as previously described.

The "in vitro" degradability study was done at the Analytical Chemistry Plant Laboratory (LQAP) from Embrapa Cerrados, located in Planaltina-DF, using techniques previously described by Mauricio et al. (1999). We measured "in vitro" degradability after 6, 24, and 48 hours of incubation.

Statistical analyses were performed in R (R Core Team, 2018) using the R package lme4 (Bates, Mächler, Bolker, & Walker, 2015). Forage data were evaluated with linear mixed-effects models, in which each measured variable was taken as a response, and both forage categories and methods for sampling were used as explanatory variables. The blocks were considered random effects. We investigated the heifers' behavior according to the different forage categories. Frequency of grazing behavior was evaluated through binary logistic regression (Korner-Nievergelt et al., 2015) multilevel (Bernoulli), while the effect on the bite rate was evaluated by multilevel linear regression. Dates and heifers were added as random effects. Model assumptions were adjusted graphically for normal distribution and homoscedasticity of the residuals, and P values were obtained by Wald Chi-square test type II ($p < 0.05$ or $p < 0.01$).

Results and discussion

The different forage categories had different CP, NDF, and ADF contents and different forage production (Table 1). Vetch grown alone and oats grown with vetch had higher protein and MM content and less ADF and NDF compared to oats grown alone. The forage production in kg/ha was also higher in the plant species when grown together. Moreover, a significant difference was noted in the rate of degradability measured at 6, 24, and 48 hours. The oats grown alone showed less degradability than the other categories (Figure 1). As for interactions, none was significant and not for any variable evaluated ($p = 0.53$).

Table 1. Means of values of forage cut by the square method after 65 days of rest (O – oat grown alone, O+V – oat grown with vetch and V – vetch grown alone). N=36.

Variables	Forage compositions[1]			SEM[2]	P-value	Random effect (SD)[3]
	O	O + V	V			
CP	14.4[b]	23.4[a]	24.5[a]	1.36	<0.01	2.62
NDF	62.98[a]	53.40[b]	53.98[b]	1.90	<0.01	2.54
ADF	34.30[a]	31.97[b]	31.13[b]	0.99	<0.01	0.00
MM	8.31[b]	8.73[a]	8.54[a]	0.27	<0.05	0.00
Forage production	686[b]	1764.2[a]	1382.1[a]	306.6	<0.01	343.8

CP: Crude protein (%), ADF: Acid detergent fiber (%), NDF: neutral detergent fiber (%), MM: mineral matter (%), and forage production (DM ha^{-1}). [1]Different letters mean significant difference (a-c). [2]Standard error of mean. [3]Block (n=6) was included as Random effect. Standard deviation (SD) of average variation of each variable (CP, ADF, NDF, MM and Yield) previewed from model is presented at each level of random effect.

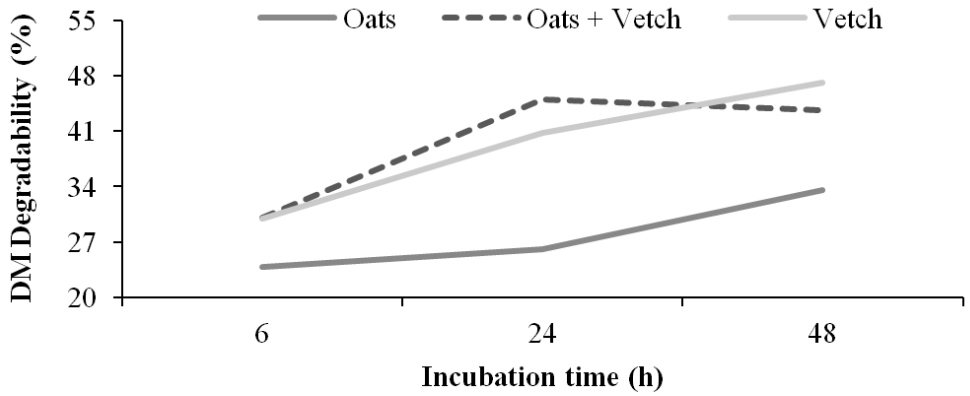

Figure 1. Dry matter degradability of different categories of forage (oats, oats + vetch, and vetch) according to incubation time (6, 24 or 48 hours).

Legumes have the natural ability to take nitrogen (N) from the atmosphere (Melesse, Steingass, Schollenberger, & Rodehutscord, 2017), which is why they are naturally higher in protein, have less fiber content, and only minor concentration of hemicellulose compared to grasses. Therefore, mixing different species of grass with legume promotes better nutritional value compared to a given species grown alone.

Forage production (kg DM ha^{-1}) was higher when oats were grown with vetch. Overall, grasses are more productive than legumes, but when grasses and legumes are grown together, under low N fertilization condition, forage production increases more than the single species grown alone (Sturludóttir et al., 2013). This results from the higher input of N in the soil (Barel, Kuyper, De Boer, Douma, & Deyn, 2017).

The inclusion of vetch in the oats grown also increased "in vitro" degradability. The "in vitro" degradability of feed simulates the amount of DM that has been fermented by the rumen microorganisms,

resulting in the production of volatile fatty acids (VFA). VFAs are the main energy source for ruminants, leading to rumen efficiency (Wanapat, 2000). Low rumen degradation rate implies higher rumen retention time (Wanapat, 2000), but a faster fermentation rate is more desirable for cattle production. Since legumes usually have a faster rate of particle-size reduction in the rumen and faster dry matter disappearance from the rumen (Rook & Yarrow, 2002), the inclusion of vetch improves this parameter.

Heifers grazed most of the time during the two hours of observation in the paddock. This expressive behavior is typically expected in cattle grazing on grass-based systems (Manning et al., 2017). Nevertheless, grazing was influenced by plant species. Grazing was longer in oats grown with vetch and vetch grown alone than that in oats grown alone (93.8, 94.0 and 87.8 ± 0.33%; $p < 0.05$, respectively). The longer time that a cow spends grazing a specific pasture could be explained in two ways. One could be associated with forage mass availability. When availability is low, heifers spend more time grazing (Manning et al., 2017). In such cases, we could also observe a higher rate of bites (Mezzalira et al., 2014). However, in instances where grazing time was longer on black oats grown with vetch, the forage mass was also greater than the forage mass of oats and vetch grown separately. Furthermore, the bite rate was similar in all three species evaluated (44.6 ± 1.18 bites min^{-1}; $p= 0.257$).

Another reason could involve the need for heifers to select their forage when confronted by the offer of two species (Hilario, Wrage-Mönnig, & Isselstein, 2017). However, forage collected by the square method did not differ from the pasture consumed by the heifers ($p =0.38$) in any of the variables investigated, which means that heifers did not select their herbage.

The selection of forage can be reduced in an intensive grazing system by the limited time heifers are in the paddock (Badgery et al., 2017). Here, we observed animals that grazed for only two hours. The VRG system promotes a voracious behavior when cows want to eat as quickly as possible because of paddock changes (Machado, 2010), thus reducing their selection. Additionally, In August, when the study was conducted, native pastureland had a low rate of growth. Thus, the two predominant cultivated species were visible on grassland.

Of these two possible explanations as to the time heifers spent eating oats and vetch, neither one fits our case; therefore, we can assume that the reason was associated with the heifers' food preferences (Chapman et al., 2007).

Overall, vetch or oats grown with vetch had similar, or basically the same, chemical composition and degradability rate. Besides, actual behavior did not change much between vetch grown separately and oats grown with vetch. However, we also need to consider the environmental benefits of mixing grasses and legumes. Even though we did not measure these benefits, the literature shows that mixing different grasses and legumes results in fewer weeds and dispenses with the need for herbicides (Barsila, 2018). This also increases the amount of C stored in the soil (Mukumbareza, Muchaonyerwa, & Chiduza, 2016) and promotes a balance of N intake and energy intake, avoiding excessive N excretion in the urine and feces (Peyraud & Delagarde, 2013). Thinking about promoting more sustainable and efficient livestock systems, it would be the differential between growing just vetch and growing vetch with oats.

Conclusion

The inclusion of common vetch with black oats increased the chemical composition of forage, the "in vitro" degradability, and forage production, thus having positive effects on the amount of time cows spent grazing.

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