Scientific Paper

Effect of the silage from *Avena sativa* L. on the productivity of grazing lactating cows

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Abstract

Objective: To evaluate the effect of the offer level of silage from *Avena sativa* L., Altoandina variety, on the total dry matter intake of the diet and the productivity of lactating cows under grazing conditions in the Pasto municipality, Colombia.

Materials and Methods: Twelve F1 cows (Kiwi cross x Holstein) were used, of 450 kg of average live weight, in a crossover design. Two treatments were established, which corresponded to two silage inclusion levels: 20 (T1) and 35 % (T2) of the total dry matter intake. Periods of 12 days were evaluated, seven of adaptation and five for measurement. Dry matter intake, milk quality and production, as well as the indicators of the metabolic profile (glucose, cholesterol and blood ureic nitrogen) were estimated. The information was processed through a variance analysis and Tukey's mean comparison test.

Results: There was significant effect (p < 0,05) for the variables total dry matter intake of the silage (2,8 *vs.* 1,4 kg/DM/cow/day for 35 and 20 % of inclusion of oat silage, respectively). The milk production was 14,9 *vs.* 14,3 kg/cow/day, for 35 and 20 % of inclusion of oat silage, respectively. The milk ureic nitrogen and blood ureic nitrogen were higher in T1 with regards to T2 (15,8 and 3,1 *vs.* 14,5 and 2,8, respectively).

Conclusions: The introduction in the diet of silage of *A. sativa*, Altoandina variety (20 and 35 %), affected the total dry matter intake. In addition, the inclusion of 35 % of the silage influenced positively milk production, increasing by 4 %.

Keywords: intake, silage, forage offer, milk production

Introduction

In the high tropic of Colombia it is usual that animal husbandry systems are based on extensive conditions, with predominance of grass monoculture, high rates of synthetic fertilization, and few forage-based supplementation options (Cardona-Iglesias *et al*., 2019). In the face of this scenario, to which the climate change is added, one of the greatest productive challenges in these systems is the variation in pasture quantity and quality throughout the year. This is influenced by the production seasonality, which causes irregularity of rainfall in the year (Jia *et al*., 2019).

In dairy systems, the above-mentioned events lead to the reduction of the forage and nutrient offer, to the decrease of voluntary dry matter intake and, thus, to the decrease of animal production (Pedraza-Martínez, 2017). Specifically, in the high tropic, this occurs with naturalized grasses, such as *Cenchrus clandestinus* Hochst. ex Chiov. and some varieties of *Lolium perenne* L. (Carulla, 2016), susceptible to frost and drought. Because of this, in most animal husbandry systems of the Colombian high tropic it is a priority to design feeding strategies that improve the ruminal energy-protein synchrony, in order to enhance animal productivity and decrease the emission of gases that contaminate the environment (Gallego-Castro *et al*., 2017; Cardona-Iglesias *et al*., 2019).

In the face of these demands, the utilization of forage materials, improved and adapted to the edaphoclimatic conditions of the region, with which good biomass yields and acceptable energy contributions can be obtained, constitutes an alternative (Makkar, 2016; Cadena-Guerrero *et al*., 2019).

Specifically, *Avena sativa* L., Altoandina variety, has been evaluated as nutritional resource for the animal husbandry systems of the region. Due to its good energy and protein contribution, high dry matter yields and good ensilability, with regards to other varieties (Campuzano-Duque *et al.,* 2018), the objective of this study was to evaluate the effect of the offer level of silage from *A. sativa*, Altoandina variety, on total dry matter intake and productivity of grazing cows.

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Materials and Methods

Location and climate. The trial was conducted between February and April, 2019, (dry season), at the Obonuco research center, of the Agrosavia corporation (former CORPOICA). This facility is located in the Obonuco village, Pasto municipality (Nariño, Colombia), at the coordinates latitude N 1°11′29,6″ and longitude 77°18′47,9″, at 2 865 m.a.s.l. The mean temperature of the region was 10 ºC, with annual rainfall of 841,57 mm and relative humidity of 83 %, conditions that correspond to the life zone Low Mountain Dry Forest (Holdridge, 2000).

Experimental animals. For the experiment 12 lactating F1 cows (Kiwi cross x Holstein) with 450 kg of live weight (LW) as average, were used, distributed in two homogeneous groups (six cows). They were animals with two parturitions, 90 days of lactation (± 20) and initial milk productions of 14 kg per day. The cows grazed *L. perenne* grasslands, 35 days old, and received oat silage 70 days after being elaborated.

Treatments and experimental design. The treatments corresponded to two levels of inclusion of *A. sativa* silage: T1 - 20 % y T2 - 35 % of the dry matter intake (DMI) of the *A. sativa* silage, from the estimated total dry matter intake (TDMI) for each animal. The TDMI/day (kg) was assumed as 3 % of the LW of the animal (13,5 kg of DM per day as average), additional to silage. It was understood that the rest of the TDMI should be from pasture (*L. perenne*).

The effect of the silage inclusion levels on the studied variables was evaluated during two measurement sequences, one of 12 days (seven days corresponded to an adaptation period and five of measurement). For the trial 12 animals (lactating cows) were used, randomized at a rate of six animals in each of the silage inclusion levels during the first measurement period. In the second sequence, the animals switched treatments. That is: the six ones that were in the inclusion level of 20 % switched to 35 %, and vice versa.

During the five days of measurement, the DM intake of *A. sativa*, milk production and compositional quality were individually recorded. For the analysis, the average of five days for each one of the evaluated variables was considered. Additionally, samples of the metabolic profile in blood were taken from each animal, during days one and twelve of each evaluation period.

Grassland management. The grazing of the animals was managed through electrical tape, according to the one that is habitually carried out. The daily grazing strip was assigned at three moments (6:00, 12:00 y 16:00 h): after the morning milking (6:00, after the afternoon milking (16:00 h) and at a more or less intermediate time (12:00), in order to make grazing more efficient. The animals had water *ad libitum*. During the study, the cows did not consume concentrate feed or any other supplement different from the *A. sativa* silage. In both treatments, the pasture offer for the animals was adjusted from the TDMI. Thus, the DMI of the pasture depended on the level of inclusion of the *A. sativa* silage.

Pasture intake. The double sampling methodology (Haydock and Shaw, 1975) was used for estimating the availability of *L. perenne*. Based on this the stocking rate (six cows/strip/day for each treatment) and strip size (40 % more of pasture considered for waste) were defined. Afterwards, the DM intake was estimated from the difference between offer and refuse. The residue left by the animals was estimated lower than 800 kg DM pasture/ha as average.

Silage intake and management. The silage (particle size 3 cm average) was offered twice per day, after each milking. The cows were transferred to a pen with access to individual feeding troughs, where they were supplied the silage ration depending on the assigned treatment. The silage intake was determined by the difference between the offer and the refuse. After silage consumption, which lasted as average 30 min., the two groups of cows were transferred to the paddock, to their respective strip, for grazing *ad libitum* until the next milking. The mineralized salt was supplied before the afternoon milking in group feeding troughs (150 g/cow/day).

Chemical composition of the diet. During the measurement days subsamples from the silage were taken directly from the bags, before it was supplied to the animals. Subsamples were also taken from the pasture of the grazing strips at the moment of sampling. They were dried in an oven, at a temperature of 65 ºC during 72 h. Then, they were sent to the laboratory of animal nutrition of the Tibaitata research center, today Agrosavia (Bogota, Colombia), where the respective bromatological analyses were conducted: dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM), total digestible nutrients (TDN), dry matter digestibility (DMD), ethereal extract (EE), crude energy (CE), net lactation energy (NLE), ash, calcium and phosphorus. For this analysis the near infrared reflectance spectroscopy (NIRS) technique (Ariza-Nieto *et al.,* 2017) was used, with analyzer NIRS DS 2500-FOSS Analytical A/S, Denmark.

Milk production and compositional quality. The milk production of each animal was recorded during the measurement periods in a milk meter (Tru-Test Milk Meters, New Zealand), at 5:00 and 15:00 h, in the milking room. During the five measurement days individual milk samples were taken. In the collected samples fat (%), protein (%), total solids (%) were determined through the infrared spectroscopy method (AOAC 972.16) (AOAC, 2015) and milk ureic nitrogen (MUN), by the infrared method (IR spectrophotometry). The samples were processed in the milk laboratory of the Obonuco-Agrosavia Research Center, with a milk analyzer FOSS Milkoscan TM 7RM, FOSS Analytical A/S, Denmark. Milk correction at 4 % of fat (FCM) was carried out according to NRC (2001) (MCF = 0,4 x kg milk + 15 x kg fat).

Metabolic profile in blood. On day 1 and 2 of each evaluation period, the animals were taken to a scale to record the live weight. A blood sample was also taken from the coccygeal vein in Vacutainer Improve® tubes (clot activator). After letting the samples rest for 10 minute, they were centrifuged at 4 000 r.p.m. during 5 minute in a HERMLE z206a centrifuge, where the blood serum was obtained. It was put in 1,5-mL Ependorf tubes and frozen at -20 ºC to determine the glucose, cholesterol and ureic nitrogen concentrations, as indicators of the energy and protein levels of the animal.

Statistical analysis. The effect of the inclusion levels of *A. sativa* silage on the evaluated variables was analyzed through a crossover design (Lui, 2016), in which the influence of the treatment factor and the sequence of the animals in each measurement period were estimated. In the cases in which the variance analysis detected significant differences between treatments, Tukey's multiple comparison test was used, with 95 % confidence. The analyses were carried out through the statistical program R Project, version 3.6.1.

Results and Discussion

Bromatological composition. Table 1 shows the bromatological composition of the silage of *A. sativa*, Altoandina variety (70 days), and of *L. perenne* (35 days).

The DM found in the silage (27 %) was higher than the report by Calpa and Melo (2003) at the Obonuco research center (Agrosavia). These authors evaluated the *A. sativa* variety, lines L-15 and Cayuse, and found DM values of 25 and 19,2 %, respectively. In the tables made by FEDNA (2016), for *A. sativa* silage with DM of 27 %, the values of fractions such as CP (8,9 %) and NLE (1,35 Mcal/kg/DM) were lower than the ones recorded in this research. Regarding pasture, the DM content (16,2 %) is in correspondence with the report by Castro *et al.* (2019) for *L. perenne* in the high tropic of Nariño, Colombia.

The CP obtained in the silage from *A. sativa*, Altoandina variety (9,3 %), was higher than the report by López *et al.* (2012), who found values of 7,2 % in *A. sativa* silages. The CP content of *L. perenne* was high (22,1 %), similar to the 24 % referred by Vargas-Martínez *et al.* (2018) for the high tropic with the same resting time (35 days).

According to Villalobos and Sánchez (2010), this pasture is characterized by good protein and energy contents, which was corroborated in this research, where NLE values of 1,43 Mcal/kg DM were found, similar to the 1,4 reported by Vargas-Martínez *et al.* (2018). Nevertheless, the NLE values of the *A. sativa* silage (1,63 Mcal/kg DM) were higher than those of the pasture. They were also higher than the ones referred by Harper *et al.* (2017) for *A. sativa* silages, with 1,5 Mcal/kg DM. Regarding the results of the NDF and ADF analysis in the silage of *A. sativa*, Altoandina variety, the values were between 49,0 and 24,5 %, respectively, for which they are in the range recommended by NRC (2001) for dairy cows.

The results corresponding to the DM (77,2 %) and TDN (71 %) in the experimental silage were higher than the 58,1 % reported by León *et al.* (2009) for the *A. sativa* silage. In the base pasture *L. perenne*, the fiber indicators were relatively low, if compared to the ones reported in tropical grasses (Molina-Botero *et al*., 2013). Meanwhile, for DMD and TDN, the indicators were high (69,1 and 63,1%, respectively).

The value of P in this study (table 1) was similar to the 0,2 % referred by León *et al.* (2009) in *A. sativa* Cayuse silage. However, the results for Ca and P were lower than the reports by FEDNA (2016) in *A. sativa* silages with 27 % DM (Ca: 0,5 % and P: 0,3 %). Although the Ca and P values in the silage of *A. sativa*, Altoandina variety, were acceptable, they should be complemented in the diet with another proportion from the forage and the mineral supplement to satisfy the nutritional requirements of these minerals.

Dry matter intake. The dry matter intake (DMI) is a highly important variable in the nutrition of dairy cows, because the nutritional and health status of these animals depend on it (Cardona-Iglesias *et al.,* 2019).

Table 1. Nutritional composition of the silage from *A. sativa,* Altoandina variety, and of the pasture *L. perenne.*

Indicator	Silage	Pasture
DM, %	27,0	16,2
CP, %	9,3	22,1
NLE, Mcal/kg DM	1,63	1,4
TDN, %	71,0	63,1
NDF, %	49,0	47,0
ADF, %	24,5	25,6
Lignin, %	9,0	6,0
DMD, %	77,2	69,1
Ca, g/kg DM	0,4	0,5
P, g/kg DM	0,2	0,2
TCHS, %	75,4	64,8
NSC, %	26,4	17,8

DM**:** dry matter; CP: crude protein; NLE: net lactation energy; TDN: total digestible nutrients, NDF: neutral detergent fiber; ADF: acid detergent fiber; Lig: lignin; DMD: DM digestibility; Ca: calcium; P: phosphorus; TCHS: total carbohydrates; NSC: non-structural carbohydrates

Table 2 shows the effect of the inclusion of different proportions of silage on the intake of dairy cows. The silage intake of the cows was higher as the offer increased (1,35 and 2,78 kg DM/silage/day for T1 and T2, respectively), which is equivalent to intakes of 5,0 and 10,3 kg of fresh silage per day.

As the silage offer was 2,7 and 4,7 kg DM/day for T1 and T2, respectively, the real intake of the silage would be equivalent to 50 % in T1, and 60 % in T2. The remainder was recorded as wasted silage.

These intakes can be considered low, if the nutritional composition of silage is taken into consideration. León *et al.* (2009) achieved intakes of up to 6,74 kg DM/day of *A. sativa* silage with regards to the live weight of Holstein cows, when they included these feedstuff preserved at 1,4 %. This is, in turn, a higher intake compared with the one reported by Yuste *et al.* (2016), who referred 5,96 kg DM/day of *A. sativa* silage silage, with 50 % Jersey x 50 % Holstein cows. The difference of intakes with regards to the literature could be related to the breed used, because it is known that Holstein animals have higher rumen size, and their nutritional requirements are also higher (Cardona-Iglesias *et al.,* 2019). It could be also associated to the applied experimental design, in which the cows (Kiwi cross x Holstein) could consume up to 35 % of the estimated TDMI in the form of silage, which for this type of animal would not exceed 5,0 kg DM, depending on the live weight and pasture availability.

Regarding *L. perenne*, the cows had an average forage offer in the strips of 13,5 kg DM/cow/day, for both treatments. In T2, they consumed 10,8 and 2,78 kg DM/day of pasture and silage, respectively, for a TDM intake/day of 13,6 kg, which was similar to the total intake in T1 (table 2). Seemingly, the cows in T2 substituted *L. perenne* by the silage from *A. sativa*, Altoandina variety, because in T1 the pasture intakes reached up to 12,4 kg/day. In both silage inclusion levels, the total NDF of the diet was 47

Table 2. Effect of two inclusion levels of silage from *A. sativa*, Altoandina variety, on the dry matter intake in lactating cows (kg/day).

Indicator	T1	SE ±	T2	SE ±	P - value
DMI silage	1,4	0,10	2,8	0,15	0,0022
DMI pasture	12,4	0,16	10,8	0,17	0,0003
TDMI	13,8	0,13	13,6	0,12	0,6788

DMI: dry matter intake, TDMI: total dry matter intake, T1- 20 % inclusion, T2-35 % inclusion of *A. sativa* silage, SE: standard error.

and 47,3 % for T1 and T2, respectively. These values, reported as optimum, increase rumination and promote the ruminal passage rate (Banakar *et al.,* 2018).

Milk production and compositional quality. Table 3 shows the results for the variables milk production and compositional quality. Milk production (FCM, L/cow/day) had significant statistical differences (p < 0,05) in favor of T2 (14,9 *vs*. 14,3 kg), being different for the other variables of compositional quality (fat, protein, total solids, %).

The milk production before the experiment was 14 kg/cow/day, similar to the 14,3 kg of T1, but lower (p < 0,05) with regards to T2 (14,9 kg/cow/day). If the TDMI data are analyzed (table 2), no significant differences among treatments are observed. The effect of 35 % DM of the silage on TDMI could have had a positive effect on milk production, which increased by 0,6 kg/cow/day (table 3).

In this study, for the two feeding systems compared (T1 and T2), data of 0,733 and 0,356 kg of NSC were obtained, by including 35 and 20 % of silage in the diet, respectively. For the NLE, the offer of 20 and 35 % of silage contributed 2,2 and 4,53 Mcal, respectively. For the two evaluated feeding systems (T1 and T2) total values of 19,9 and 20 Mcal/kg DM of NLE were observed.

In the high tropic of Colombia, Mojica *et al.* (2009) studied the effect of restricting the offer of *C. clandestinus* and the inclusion of 0; 0,7 and 1,4 % of *A. sativa* silage with regards to LW on productive variables of Holstein cows. The supplementation with the silage did not affect the daily production of milk/cow (p > 0,05). These authors reported values of 22,2 kg/cow/day (0 % inclusion of silage); 20,1 kg/cow/day (0,7 % inclusion) and 20,1 kg/cow/day (1,4 % inclusion). Álvarez and Bernal (2018), also with Holstein cows, achieved higher milk production (p < 0,05) in cows that grazed *C. clandestinus*, supplemented with *A. sativa* silage (15,07 kg/cow/day), compared with those that only grazed the grass (12,3 kg/cow/day).

In this study, no statistically significant differences were found (p > 0,05) for the content of fat, protein and total solids (%) of the milk between treatments. The fat and protein values were in the normal ranges for the breed and management type, and were similar to the ones obtained by Yuste *et al.* (2016) in the high tropic of Costa Rica, who worked with Jersey-biotype cows (350 kg LW), which grazed *C. clandestinus* and received 1,5 kg DM of *A. sativa* silage. The NDF data in both treatments were adjusted to the suggestions made by NRC (2001) and are mostly from the forage (> 75 %). Banakar *et al.* (2018) reported that when there is adequate intake of effective fiber, rumination and salivation improve, and adequate pH is obtained at rumen level, which favors the synthesis of milk fat.

There were significant statistical differences (p < 0,05) for the variable MUN, with values of 15,7 and 14,4 for T1 and T2, respectively, although they are considered in the normal range, between 12 and 18 mg/dL. Possibly, in T2, as it is the diet that contributed the highest quantity of NSC, there was better utilization of N; thus, less MUN was shown. According to the above-explained facts, Drudik *et al.* (2007) indicated that an adequate MUN level shows good balance between degradable protein and adequate fermentation rate of non-structural carbohydrates (NSC) at rumen level.

The data of this work coincide with the report by Meyer *et al.* (2006), who referred a positive relation between MUN level and fat percentage in milk. On the other hand, Montoya *et al.* (2017) agree that the high MUN levels (> 18mg/dL) can be related to nutritional unbalances in dairy systems. Acosta *et al.* (2005) arrived at a similar conclusion with low MUN values (< 9 mg/dL).

Indicators of the metabolic profile. Table 4 shows the results of the variables of the metabolic

Table 3. Effect of two inclusion levels of silage from *A. sativa*, Altoandina variety, on the milk production and compositional quality in lactating cows.

Indicator	T1	SE ±	T2	SE ±	P - value
MP, kg/cow/day (FCM)	14,3	0,38	14,9	0,47	0,0490
Fat content, %	4,5	0,11	4,2	0,12	0,0560
Protein content, %	3,8	0,04	3,7	0,04	0,0587
Content of total solids, %	13,2	0,47	13,3	0,47	0,3953
MUN, mg/ dL	15,7	0,37	14,4	0,37	0,0477

T1-20 % inclusion of *A. Sativa* silage; T2-35 % inclusion of *A. sativa* silage; FCM: fat corrected milk.
MUN: milk ureic nitrogen

profile. No statistical differences were shown between treatments for the variables cholesterol and glucose in blood (mmol/L); but they were observed for the BUN levels (p < 0,05). They were 3,1 and 2,8 mmol/L for T1 and T2, respectively, following the same trend as MUN (mg/dL). This is due to the fact that both indicators are closely related. Thus, urea in blood is easily disseminated towards the blood system of the mammary gland, for which when measuring urea in blood or milk, similar results will generally be obtained (Kauffman *et al.,* 2001).

These BUN values are within the normal ranges for lactating cows, which should not exceed 6,94 mmol/L. in dairy cows values over the above-referred ones are associated with low fertility indexes, of up to 20 % (Rhoads *et al.,* 2004). In this regard, Campos *et al.* (2007), in the Colombian southwest, reported in grazing Holstein and Jersey cows, BUN values of 3,7 and 3,3 mmol/L, respectively, which were slightly higher than the ones in this study.

Regarding the cholesterol results, in this research, in both treatments, they were over the normal range, which suggests values between 1,5 and 2,28 mmol/L (Kolver, 2003). This could have been due to the days into lactation of the animals, which did not exceed 110 days. As referred by Seifi *et al.* (2007), the cholesterol values decrease, especially, after the second third of lactation. Nevertheless, those in this work were similar to the ones reported by Gómez-Osorio *et al.* (2017) for crossed cows (*Bos indicus* x *Bos taurus*), supplemented with propylene glycol. These authors obtained values of 2,9 mmol/L, which were higher than those referred by Campos *et al.* (2007) for Jersey cows (2,3 mmol/L), breed types related to the ones evaluated in this study.

In this work, the glucose concentrations of the cows for both treatments were in the normal range, between 2,5 and 4,6 mmol/L. According to Macrae *et al.* (2006), the glucose values in lactating cows should be over 3 mmol/L. Lower values would indicate that the animals could start to perform gluconeogenesis in order to balance the glucose requirement, by using the propionate in the liver as precursor.

Conclusions

The introduction in the diet of silage from *A. sativa*, Altoandina variety (20 and 35 %), did not affect the TDMI. In addition, the inclusion of 35 % of silage had a positive effect on milk production, which increased by 4 %; while milk quality and most of the indicators of the metabolic profile remained similar with both values of silage inclusion.

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Authors' contribution

- Edwin Castro-Rincón. Did the conceptualization, elaborated the methodology and supervised the research.
- Juan Leonardo Cardona-Iglesias. Conducted the research, wrote and revised the manuscript.
- Filadelfo Hernandez- Oviedo. Conducted the research, data processing and wrote the original draft.
- Martín Valenzuela-Chiran. Conducted the research, data processing and wrote the original draft.

Conflict of interests

The authors declare that there are no conflicts of interests among them.

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Table 4. Effect of two inclusion levels of silage from A. sativa, Altoandina variety, on indicators of the metabolic profile of lactating cows.

Indicator	T1	SE ±	T2	SE ±	P - value
BUN, mmol/L	3,1	0,26	2,8	0,26	0,0001
Cholesterol, mmol/L	2,6	0,34	2,8	0,33	0,2445
Glucose, mmol/L	4,1	0,44	4,27	0,45	0,2642

T1-20 % inclusion *A. sativa* silage; T2-35 % inclusion *A. sativa* silage; BUN: blood ureic nitrogen; mmol/L

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