Scientific Paper

Utilization of byproducts from *Saccharum officinarum* L. in the supplementation of lactating cows in Colombia

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Abstract

Objective: To evaluate two supplements elaborated with *Saccharum officinarum* L. bagasse, molasses and two levels of urea, on the milk production and quality of first-parturition cows in Nariño, Colombia.

Materials and Methods: Six first-parturition F1 cows (Kiwi Cross x Holstein) were used, in a replicated Latin square design. Three treatments were established: T0) control, only grazing; T1) grazing plus supplement 1 and T2) grazing plus supplement 2. The dry matter intake, milk production, fat production, protein production, production of total solids, fat percentage and protein percentage, percentage of total solids, as well as milk ureic nitrogen, were estimated. The information was processed through a variance analysis and Tukey's mean comparison test.

Results: There was effect of supplementation on the variables dry matter intake, milk production, production of total solids ($p < 0{,}05$), where T1 and T2 showed the best averages, with values of 14 and 14,7 kg/day for dry matter intake; 9,1 and 9,0 kg/cow/day for milk production and 1 356,9 and 1 359,8 g/cow/day for the production of total solids, respectively. Likewise, there were differences in the variable milk ureic nitrogen, where T1 had value of 14,3 mg/dL, with regards to T0 and T2, which reached 16,3 and 16,7 mg/dL, respectively.

Conclusions: The *S. officinarum* byproducts, with adequate urea inclusion levels, can improve the contribution of nutrients and, thus, the productive parameters in lactating cows. Yet, T1 showed the best averages in milk production and quality and the lowest content of milk ureic nitrogen.

Keywords: intake, molasses, urea, bagasse, milk production

Introduction

Saccharum officinarum L. is a plant of the genus *Saccharum*, family *Gramineae,* order *Glumiflorae*, class *Monocotyledonae* (Osorio, 2007). It is an important commercial crop and one of the main sources of sugar, ethanol, brown sugar and panela worldwide. Brazil leads the list of the main manufacturers, with annual production of 752 895 thousands of metric tons (Tm), and Colombia occupies the seventh place, with annual production of 32 662 Tm (FAOSTAT, 2019).

One of the limitations shown by *S. officinarum* agroindustry in Colombia is the low utilization of byproducts from *S. officinarum* and its grinding, although the quantity and volume of utilizable byproducts are potentially high. Depending on the percentage of juice extraction, variety and age of the crop, 2 368 kg of bagasse, 300 kg of filter cake and 150 kg of molasses can be obtained, as average, per each ton of sugar obtained without refining (Santos *et al*., 2020).

The byproducts generated from the processing of *S. officinarum* constitute raw materials for the elaboration of supplements, aimed at feeding ruminants, especially in feed scarcity seasons, in different forms of use and variations, with the additions of other substances that can improve the nutrient availability and digestibility (Berman-Delgado, 2011; Fernández-Méndez, 2018).

Bagasse is one of the byproducts that are generated in higher proportion in *S. officinarum* agroindustry. Due to its fiber content (33,3 %) and energy contribution it has shown satisfactory and low-cost results, when it has been used as single fibrous source or as supplement of different rations, up to 30 % sugars remaining in such material (Lagos and Castro, 2019).

The juice that results from the dehydration of filter cake has replaced molasses as source of energy (1,9 Mcal/kg digestible energy) or as agglutinant in the elaboration of multinutritional blocks for fattening steers. Nevertheless, these byproducts show low protein contents, for which they should be complemented with nitrogen sources such as urea. Diverse studies have proven that the supply of the mixture of molasses and urea increases

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intake of low-quality forage, cellulose degradation and passage rate of feedstuffs through the rumen, which improves the utilization of pastures (Pachón *et al.*, 2005).

Dairy cattle husbandry in the high Colombian tropic has problems, related to the low quantity of available forage, as consequence of inadequate agronomic managements of the pastures, and due to events of climate change, such as prolonged periods of low rainfall (Castro-Rincón *et al.*, 2019; Cardona-Iglesias *et al.*, 2020). Farmers have introduced pasture species with high protein levels, in order to improve the compositional quality of milk, but with low fiber contents, which causes an energy deficit and unbalance in the diets (González-Guarín, 2016). In view of these conditions, the farmer needs to supplement with fibrous or energy feedstuffs to prevent diseases and production decrease. The most common option is the utilization of concentrate feeds, which is generally translated into the increase of production costs (Cardona-Iglesias *et al.*, 2019a).

The objective of this study was to evaluate two supplements elaborated with *S. officinarum* bagasse, molasses and two urea levels, on the milk production and quality of first-parturition cows.

Materials and Methods

Location and climate. The research was conducted between March and May, 2018, in the dairy farm of the Obonuco Research Center of the Colombian Corporation of Agricultural Research (AGROSAVIA), Pasto municipality, Nariño, Colombia. This facility is located at 2 905 m.a.s.l., 01°11´28,3´ N, 77°19´08,8´´W, with average annual temperature of 12 ºC, relative humidity of 77 % and average annual rainfall of 950 mm, according to data obtained from the meteorological station (Vintage station pro 2) located at the Obonuco Research Center in 2018.

Experimental design and treatments. A 3 x 3 replicated Latin square experimental design was used, with three treatments: T0 (grazing), T1 (grazing + supplement 1) and T2 (grazing + supplement 2), with three periods of 15 days each. The cows were randomly assigned in pairs to each treatment and were alternated every 15 days, so that all of them went through the three treatments. Three evaluation periods were established, of 15 days each. The first seven days corresponded to the adaptation period, and the next eight days were used as measurement stage. The supply of supplements was done in individual feeding troughs and at two moments: in the morning milking (5:00 a.m.) and in the afternoon milking (3:00 p.m.).

Experimental animals. Six first-parturition F1 cows (Kiwi Cross x Holstein) were used, which at the beginning of the experiment had, as average, 170 days of lactation (± 15 days), production of 8,2 kg/cow/day and live weight of 450 kg. The water consumption was *ad libitum*. The cows remained in paddocks of *Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone pasture. Rotational grazing with electrical fence was performed, daily adjusting the intake of dry matter (DM) which came from the forage. The fence was moved three times per day (6:00 a.m., 11:00 a.m. and 4:00 p.m.) to make grazing more effective. The occupation of each strip was one day and the resting period for the *C. clandestinus* pasture, 35 days.

Supplement intake and management. Before the elaboration of the supplement, a nutritional balance was performed. For such purpose the contribution of the consumed forage and the nutritional requirements of the animals, according to the NRC (2001), were taken into consideration. Supposedly the deficit should have been covered with the supply of two supplements, based on molasses and bagasse, as byproducts of panela *S. officinarum* and energy source for the cattle; the supplements also included *Zea mays* L. bran and two inclusions of urea, according to Garríz and López (2002).

The formulation of the supplements is shown in table 1. To each animal three kilograms of DM of the supplement were daily supplied, which were offered in equal parts after each milking time in individual feeding troughs.

Table 1. Formulation of supplements elaborated with *S. officinarum* byproducts, with inclusion of two levels of urea.

Ingredient¥	Supplement 1	Supplement 2
S. officinarum molasses	65,0	65,0
S. officinarum bagasse	22,0	20,5
Z. mays bran	10,0	10,0
Urea	3,0	4,5

¥ DM percentage

Evaluated variables. To determine the chemical composition of the diet, in the measurement periods samples of the grass in paddock were taken through manual cutting (Bonnet *et al.*, 2011). At the end of the measurement period a mixture of the samples was performed. They were dried in air-forced stove, at 65 ºC, during 72 h, and were later ground in a stationary mill with a mesh of 1,0 mm. in order to analyze the chemical composition of the feedstuffs: dry matter (DM), crude protein (CP), neutral detergent fiber

(NDF), acid detergent fiber (ADF), hemicellulose, lignin, ethereal extract (EE), crude energy (CE), net lactation energy (NLE), ash, calcium (Ca) and phosphorus (P), the near infrared reflectance spectroscopy technique (NIRS DS 2500 – FOSS Analytical A/S – Denmark) (Ariza-Nieto *et al*., 2018) was used. For the raw materials and the supplements, the samples were analyzed through analytical techniques of the Association of Official Analytical Chemists (AOAC, 2005). Regarding Ca, it was determined according to complexometric evaluation with EDTA, and for P, UV-VIS (NTC 498) spectrometry was used. The total ash was analyzed by direct incineration (AOAC 942.05). For the NDF the procedure proposed by Van Soest (AOAC 973.18) was followed, for ADF, according to the rules of AOAC (962.09 and 978.10), just like for the ethereal extract (AOAC ID 973.18). Regarding moisture, the thermogravimetric analysis IR was applied, and for the CP, Kjeldahl (NTC 4657).

Table 2 shows the compositional quality of the raw materials used in the elaboration of the supplements.

In situ degradation of the supplement. Additional to the compositional quality, the *in situ* degradation of dry matter (ISDMD), crude protein (ISCPD), and neutral detergent fiber (ISNDFD) of the supplements was determined at 48 h of incubation, for which the nylon bag technique, described by Ørskov and McDonald (1979), was applied.

Dry matter intake. The grazing area was daily adjusted to ensure a theoretical DM offer per animal of 3 kg DM/100kg LW. The DM intake of the forage was measured through the agronomic method (entrance and departure) and the quantity of average pasture consumed by each animal was estimated. It was assumed that the difference between the capacity of entrance and that of departure was the quantity of consumed forage. For carrying out the calculation of *C. clandestinus* the double-sampling methodology proposed by Haydock and Shaw (1975) was used. Likewise, the quantity of supplement consumed by the cows, product of the offer less the refuse, was measured. The total dry matter intake (TDMI) was the sum of pasture and supplement, expressed in DM units.

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 a.m. and 3:00 p.m., in the milking room. During the last five days of the measurement period milk samples were taken from each cow, in both milking times. On the collected samples fat (%), protein (%) and 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 FOSS Milkoscan TM 7RM, FOSS Analytical A/S, Denmark, equipment. The data milk production (MP, kg/cow/day) and milk compositional quality, which comprised protein production (PP, g/cow/day), fat production (FP, g/cow/day), production

Table 2. Compositional quality of the raw materials.

Composition	*S. officinarum* molasses	*S. officinarum* bagasse	*Z. mays* bran
DM, %	44,8	44,6	97,7
CP, %	11,1	2,2	12,6
EE, %	4,9	0,4	9,2
NDF, %	-	71,8	23,4
ADF, %	-	40,7	21,8
HEM, %	-	31,1	1,6
CEL, %	-	34,1	20,9
LIG, %	-	6,6	0,9
NSC, %	73,4	23,4	49,6
ASH, %	10,7	2,3	5,3
P, %	0,1	0,1	0,0
Ca, %	0,1	0,1	0,1
CE (Kcal/kg)	4,2	2,7	3,3

DM: dry matter, CP: crude protein, EE: Ethereal extract, NDF: neutral detergent fiber, ADF: acid detergent fiber, HEM: hemicellulose, CEL: cellulose, LIG: lignin, NSC: non-structural carbohydrates, ASH: ash, P: phosphorus, Ca: calcium, CE: crude energy of total solids (TSP, g/cow/day) and milk ureic nitrogen (MUN, mg/dL), were analyzed.

Statistical analysis. The data were analyzed by means of the statistical package SAS (V 9.4), through a mixed model with the aid of the GLM procedure. The animal and the period were considered random effects and the treatment, a fixed effect. Mean comparisons were done by Tukey's test (p< 0,05).

Results and Discussion

In the evaluated supplements DM content of 52 % was found, much higher than the DM of the basis pasture used (table 3).

According to Lagos and Castro (2019), one of the attributes of the utilization of the supplements that contain *S. officinarum* byproducts, is that they can increase the energy density and DM of the diet. Supplement 2, which had 1,5 % more urea with regards to 1, showed higher CP, ISDMD, ISCPD and ISNDFD values. The CP, ISDMD and ISCPD were higher than the report for *C. clandestinus*. Souza *et al.* (2015) stated that the addition of urea in supplements for ruminants can make the action of rumen microorganisms more efficient, which improves the total degradability of the ration, especially of fiber (table 3).

The NSC values of both supplements were numerically higher than those of the pasture (18 *vs* 16 %). Villalobos and Sánchez (2010) stated that the proportion of NSCs is inversely proportional to the fiber content and DM digestibility. In turn, it is related to the high-availability energy in the diet and the efficiency of utilization of degradable protein (Castro-Rincón *et al.*, 2019). These criteria coincide with the observations made in this study, in which the supplements had higher content of NSC and IVDMD, but lower value of NDF, with regards to *C. clandestinus.*

The *in situ* DM degradability in *C. clandestinus* (60 %) was lower than the one reported by Duque-Quintero *et al.* (2017), who found a degradability value of 69 %. But it was higher than the 37 % obtained by Correa *et al.* (2012), although this last value was for an incubation period of 12 h (table 3).

A very important fraction to feed dairy cows is the NLE, because milk production depends on its concentration in the diet (Castro-Rincón *et al.,* 2019; Cardona-Iglesias *et al.,* 2020). Both supplements had

Table 3. *In situ* compositional quality and net lactation energy of supplements of panela *S. officinarum* and *C. clandestinus*

Composition	Supplement 1	Supplement 2	*C. clandestinus*
DM, %	51,6	52,4	16,1
CP, %	17,4	21,5	18,2
EE, %	13,6	13,9	2,1
NDF, %	42,8	38,8	53,2
ADF, %	21,0	20,2	28,0
HEM, %	21,8	18,6	23,0
CEL, %	19,1	18,2	20,1
LIG, %	1,9	2,0	6,1
NSC, %	18,0	18,0	16,0
ASH, %	8,6	7,9	9,5
P, %	0,2	0,2	0,5
Ca, %	0,3	0.2	0,4
NLE (Mcal/kg DM)	2,1	2,2	1,3
ISDMD, %	68,0	73,0	60,0
ISCPD, %	87,0	90,0	59,0
ISNDFD, %	38,0	43,0	50,0

DM: dry matter, CP: crude protein, EE: ethereal extract, NDF: neutral detergent fiber, ADF: acid detergent fiber, HEM: hemicellulose, CEL: cellulose, LIG: lignin, NSC: non-structural carbohydrates, ASH: ash, P: phosphorus, Ca: calcium, NLE: net lactation energy, ISDMD: *in situ* DM digestibility, ISCPD: *in situ* crude protein digestibility, ISNDFD: *in situ* neutral detergent fiber digestibility higher NLE value (Mcal/kg DM) compared with *C. clandestinus* (S1 2,1; S2 2,15 *vs C. clandestinus* 1,3). Jaramillo-Arango and Cuervo-Vivas (2017) indicate that the byproducts of *S. officinarum* are a very good energy source, which enhances milk production, as long as they are combined with other nutrient sources such as protein. The NLE value of *C. clandestinus* in this study (1,3 Mcl/kg DM) is in agreement with the average reported in several works for the high Colombian tropic, which denotes the need to supplement with energy sources in this type of animal husbandry system (Vargas-Martínez *et al.,* 2018; Cardona-Iglesias *et al.,* 2019a).

Regarding the intake of supplements (table 4), the 3 kg DM/animal/day offered were consumed. For such authors as Castaño *et al.* (2012), the intake of supplements that contain *S. officinarum* byproducts depends on the inclusion levels, composition and supply form. It was observed that the intake of *C. clandestinus* was higher (p < 0,05) for the animals that were not supplemented (T0), which consumed 1,6 and 0,9 kg DM more, compared with those of T1 and T2. Nevertheless, when observing the daily TDMI, it could be noted that the animals in the treatments that included the supplements consumed more TDM/day than in the control (p < 0,05).

In this research, the intake values for *C. clandestinum* pasture coincide with the average of 11 kg DM/day, reported for animal husbandry systems in the high Colombian tropic. According to diverse authors, the *C. clandestinus* intake is limited, mainly, by its high NDF content (Correa-Jiménez, 2012; Mejía-Díaz *et al.,* 2017; Cardona-Iglesias *et al.,* 2019a; 2019b).

The TDM intake for all the treatments is within the ranges reported for the animal biotype used in this research, with the crossings between the Kiwi cross and Holstein breeds (Cardona *et al.,* 2019a; Castro-Rincón *et al.,* 2019). Although no statistical differences were shown, increase was observed in the pasture intake of the animals with T2 (higher addition of urea) compared with T1, which would be related to the improvement in the energy-protein balance promoted by energy sources such as *S. officinarum*, and that would improve digestibility, passage rate and, thus, intake (Lagos and Castro, 2019).

The intake of the supplements did not have effect on the FP, PP, F, P and TS. The animals that received treatments 1 and 2 showed a significance response in MP, TSP and MUN (p < 0,05), with regards to the control (table 5).

In this study a positive effect was observed on the volume, milk production and production of total solids, by obtaining 8 kg/cow/day in the MP and 1 175,8 g/cow/day in TSP for the cows without supplementation. Meanwhile, for the cows fed with the supplements, MP of 9,2 kg/cow/day and 9 kg/cow/day, TSP of 1 359,8 g/cow/day and 1 359,8 g/cow/day, were recorded for the cows fed with T1 and T2, respectively. This proves that the use of non-protein nitrogen in the mixture with energy sources, such as molasses and bagasse, as energy supplementation during lactation, increased by 15 ad 12,5 % the production with regards to the record in cows which were not exposed to supplementation.

Providing the energy requirements of dairy cows is one of the factors that has higher incidence on milk production and quality (Valderrama-Lagos, 2019). Energy unbalance, before and after parturition, whether due to excess or defect, can lead to metabolic disorders and decreases in milk production (Hoffman *et al*., 2017).

These results could be due to the fact that the supplemented cows received an adequate contribution of DM (14 and 14,7 kg/day), if compared with the ones that were not supplemented (12,6 kg/day), whose proportion was below 3 % of their live weight, and under grazing conditions a temporary energy deficit would be occurring, which would be compensated with the body reserves (Marques *et al*, 2016).

The energy level of the supplements S1 and S2 (2,1 and 2,15 Mcal/kg DM, respectively) was higher

Table 4. Effect of the supplements based on byproducts of panela sugarcane and two inclusions of urea on the dry matter intake in lactating cows.

Indicator	T0	T1	T2	SEM ±	P – value
DMI supplement, kg/day	0	3	3	0,100	0,0123
DMI of *C. clandestinus*, kg/day	12,6^{a}	11,0^{b}	11,7^{b}	0,140	0,0345
TDMI, kg/day	12,6^{b}	14,0^{a}	14,7^{a}	0,120	0,0491

a, b: different letters in the same row indicate differences (p < 0,05)
DMI dry matter intake, TDMI total dry matter intake, SEM standard error of the mean
T0: grazing of *C. clandestinus*, T1: grazing of *C. clandestinus* + supplement 1, T2: grazing of *C. clandestinus* + supplement 2

Table 5. Milk production and composition of lactating cows, supplemented with *S. officinarum* byproducts and two levels of urea.

Indicator	Treatments			SEM ±	P - value
	T0	T1	T2		
Milk production, kg/cow/day	8,0[b]	9,2[a]	9,0[a]	0,200	0,001
Fat production, g/cow/day	388,8	434,8	392,9	17,700	0,14
Protein production, g/cow/day	294,3	336,7	326,2	12,700	0,06
Production of TS, g/cow/day	1 175,8[b]	1 356,9[a]	1 359,8[a]	12,700	0,05
Milk composition					
Fat, %	4,6	4,6	4,3	0,100	0,07
Protein, %	3,5	3,6	3,6	0,000	0,12
Total solids, %	13,8	14,2	15	0,500	0,15
MUN, mg/dL*	16,3[a]	14,3[b]	16,7[a]	0,300	0,001

a, b: Different letters in the same row indicate differences (p < 0,05)
¥MUN milk ureic nitrogen, TS total solids
T0: grazing of *C. clandestinus*, T1: grazing of *C. clandestinus* + supplement 1 and T2: grazing of *C. clandestinus* + supplement 2

than that of pasture, which allowed to improve the energy contribution in the diet of the cows and achieved a positive response in MP and TSP.

López-Ordaz *et al.* (2011) state that the addition of extra energy to the diet of lactating cows, along with low NDF contents, improve the utilization of the feedstuff, which allows higher intestinal absorption and better production of metabolites, resulting in increases of MP.

In a study conducted with crossbred double-purpose cattle, it was found that the utilization of supplements elaborated with *S. officinarum* byproducts in mixture with molasses could increase the MP between 1 and 2 kg/cow/day, but with reductions in its quality (Jaramillo-Arango and Cuervo-Vivas, 2017). These results differ from the ones found in this research, in which the MP was improved (1,0 and 1,2 k/cow/day with T1 and T2, respectively), without detriment of milk quality. This can be ascribed to the fact that in the above-cited experiment the control treatment had higher proportion of NSC.

The changes in milk production and composition can be related to the level of protein, soluble carbohydrates and basis diet (Reynolds *et al.,* 2011), conditions that in this research could be im proved with the contribution of the supplements, with higher content of NSC (18 %) with regards to *C. clandestinus* (16 %), higher ISDMD (68 and 73 %) and ISCPD (87 and 90 %) of the supplements. López-Ordaz *et al.* (2011) indicate that the diets with higher digestibility increase the recycling of urea in the rumen, flow of microbial protein to the small intestine, synthesis of glucose in the liver and consumption of glucose and amino acids by the mammary gland, which possibly justifies the increase in MP.

The results for the variable MUN (table 5) for all the treatments are within the reference values for lactating cows (Vargas-Sobrado *et al.,* 2016). However, T1 had the lowest MUN value compared with T0 and T2. This metabolic indicator was affected, mainly, by the protein-energy ratio of the diet, as well as by the unbalance in the intake of degradable or non-degradable protein in rumen, and of both (Correa-Jiménez, 2012).

Acosta *et al.* (2005) express that in order to make an adequate analysis of this indicator the protein percentage in the milk should be considered, which is directly related to the energy contribution of the diet and the lactation stage. These authors establish that for the mid and late stage of lactation (>150 DPP), with P>3,4 % and MUN from 12 to 18 mg/dL there is adequate balance of amino acids and NLE. In this regard, Bonifaz and Gutiérrez (2013) suggest that the advisable MUN values are between 12 and 15 mg/dL and between 15 and 18 mg/dL. Results not comprised in these intervals would represent moderate risk, because when there is protein deficit or excess the quantity of N necessary for microbial multiplication could be affected, and microorganisms would be forced to utilize peptides as energy source.

In this study, the cows fed with T1 reached P values of 3,6 %, and 14,6 mg/dL of MUN. In treatments T0 and T2, with protein percentages of 3,5 and 3,6 % in the milk, the MUN values were 16,3 and 16,7 mg/dL, respectively, condition that proves that T1 showed an adequate protein-energy ratio.

Conclusions

The *S. officinarum* byproducts with adequate levels of urea inclusion can improve the contribution of nutrients and, thus, the productive parameters in lactating cows. However, T1 showed the best averages in milk production and quality, and the lowest milk ureic nitrogen content in the evaluated animals.

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Conflict of interests

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

Authors' contribution

- Elizabeth Lagos-Burbano. Contributed to the design of the methodology, conducted the research and carried out the writing of the original draft, data analysis, manuscript revision and edition.
- Yeferson Andrés Bran-Miranda. Contributed to the design of the methodology, conducted the research and carried out the writing of the original draft, data analysis, manuscript revision and edition.
- Edwin Castro-Rincón. Contributed to the design of the methodology, conducted the research and carried out the writing of the original draft, data analysis, manuscript revision and edition.
- Juan Leonardo Cardona-Iglesias. Contributed to the design of the methodology, conducted the research and carried out the writing of the original draft, data analysis, manuscript revision and edition.

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