Scientific Paper

Effect of the inclusion of *Musa* sp. on the conservation of silages of *Trichanthera gigantea* (Humb. & Bonpl.) Nees

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Abstract

Objective: To evaluate the effect of the inclusion of different levels of *Musa* sp. on the nutritional and fermentative quality of *Trichanthera gigantea* (Humb. & Bonpl.) Nees.

Materials and Methods: A complete unrestricted design was used, with four treatments: T1) 100 % *T. gigantea*, T2) 85 % *T. gigantea*: 25 % *Musa* sp., T3) 70 % *T. gigantea*: 30 % *Musa* sp. and T4) 55 % *T. gigantea*: 45 % *Musa* sp. The silages were made in 5-kg plastic bags during 40 days. At the moment of opening their bromatological characteristics, as well as the fermentation indicators, were measured. A variance analysis was applied and the possible correlations among all the bromatological variables, as well as fermentation indicators, were measured. A variance analysis was applied and the possible correlations among all the bromatological variables and fermentative indicators, were analyzed.

Results: Improvement was found in the fermentative indicators of the silages due to increase in the concentration of lactic acid and pH decrease, proportional to the quantity of *Musa* sp. used. The dry matter concentration increased, at a rate of a 0,9 percentage points for each increase of *Musa* sp. in the silages. Likewise, increase was generated in the content of non-fibrous carbohydrates and starch, which improved the energy contribution of the silages. There was decrease in the quantity of crude protein and fiber, at a rate of 1,8 and 5,7 percentage points for each increase in the quantity of *Musa* sp., respectively, without negative effect on the digestibility of the silages.

Conclusions: The mixtures with 30 % *Musa* sp. showed adequate fermentative and nutritional characteristics for their conservation and use as supplement for ruminants; nevertheless, levels 0 and 5 % showed the highest protein and fiber values, but low in energy. In turn, the mixtures of 0 and 45 % achieved the best fermentative indicators.

Keywords: nutritional quality, ruminant nutrition, forage shrubs

Introduction

In tropical production systems, pastures are used as main feed source. Yet, this resource is affected due to the environmental conditions, which can compromise the adequate intake of nutrients and animal productivity (Poppi *et al.,* 2018).

The use of shrubs as complement of pastures and forage source can help mitigate the effects caused by the climate change (Alayon-Gamboa *et al*., 2016), because it is considered a profitable alternative that allows to provide the animals with nutrients, mainly with protein (Franzel *et al*., 2014). Nevertheless, for utilizing better these feedstuffs, they should be complemented with energy sources that optimize the use of nutrients in the rumen (Jiménez-Ferrer *et al*., 2015).

Trichanthera gigantea (Humb. & Bonpl.) Nees is a tropical plant from humid climate zones. It has nutritional characteristics, among which a protein content between 18 and 30 % and dry matter digestibility of 69 %, stand out (Riascos-Vallejo *et al.*, 2020), which turn it into a choice for ruminant feeding, fresh as well as in silage (Daniel, 2015).

Square banana (*Musa acuminata* x *Musa balbisiana*, Grupo ABB) (SB) has proven to be an energy source, due to its high starch content (80,1 % DM). In addition, it is suitable for rumen supplementation, because it can be preserved as silage, especially when it is used in immature state (López, 2017; López-Herrera *et al.,* 2019). This characteristic makes it a viable alternative for its mixture with plants such as *T. gigantea*, in order to favor the fermentation process in the silage and enhance the use of nutrients at rumen level (López-Herrera *et al*., 2019).

Silage is the result of a process of spontaneous lactic fermentation, which occurs under anaerobic conditions. It is induced by the bacteria that are part of the epiphytic microflora in plants, particu-

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larly those that produce lactic acid (Borreani *et al.*, 2018). Through the ensiling techniques diverse type of materials that can be used in ruminant feeding have been preserved (Grant and Ferraretto, 2018).

The objective of this research was to evaluate the effect of the inclusion of different levels of *Musa* sp. on some indicators of the nutritional and fermentative quality of *T. gigantea* silages.

Materials and Methods

Location. The research was carried out in the Experimental Farm Santa Lucía (FESL, for its initials in Spanish), of the National University of Costa Rica. This facility is located between coordinates 10° 01' 20'' N and 84° 06' 45'' W, at an altitude of 1 250 m.a.s.l., in Barva, Heredia, Costa Rica. The laboratory analyses were carried out at the Animal Nutrition Research Center of the University of Costa Rica, located in Montes de Oca, Costa Rica.

Experimental design and treatments. A complete randomized unrestricted design was used, in which four levels of substitution of *T. gigantea* forage by *Musa* sp. fruits (SB) were combined, according to the following treatments: T1) 100 % *T. gigantea*, T2) 85 % *T. gigantea*: 25 % SB, T3) 70 % *T. gigantea*: 30 % SB and T4) 55 % *T. gigantea*: 45 % SB. All the treatments were subject to conservation through the technique of silage in microsilos. To all of them 6 % weight/weight of sugarcane (*Saccharum officinarum* L.) molasses without being diluted and artisanal bacterial inoculant (elaborated by the fermentation of milk serum, skimmed milk and molasses, during 30 days) with a Lactobacillus concentration of 1,0 x 10^9, at doses of 1 L/ton in fresh, were added. Likewise, each treatment was repeated four times for a total of 16 experimental units (microsilos).

Experimental procedure

Materials used. The *T. gigantea* forage was obtained from a plantation located in the FESL. This zone shows annual rainfall of 2 403 mm, relative humidity of 80,5 % and mean annual temperature of 20,3 ºC, with minimum of 15,4 ºC and maximum of 25,2 ºC (IMN, 2020). The material was harvested from a plantation established in 2004, with asexual seed, at a density of 20 000 plants per hectare. During the experimental period it only received weed control. It was harvested at 75 days of age of the regrowth and at 1 m of height. Once collected, before the elaboration of the silages, it was subject to a dehydration process during 48 hours in a greenhouse to reduce the moisture content.

The fruits from SB (*Musa acuminata* x *Musa balbisiana*, Group ABB) were harvested in the Agroecological Farm Vocaré, located in Upala, Costa Rica, a zone situated at 120-180 m.a.s.l., with average rainfall of 2 500 mm per year, average temperature of 26 ºC and relative humidity of 80-90 % (IMN, 2020). The nutritional composition before the silage of the materials used is shown in table 1.

Table 1. Nutritional value of the materials used in the preparation of the mixtures to be ensiled (% DM).

Nutrient	*Musa* sp.	Pre-dried *T. gigantea*
DM	28,3	16,9
CP	5,1	19,9
NDF	8,7	30,6
Lignin	5,1	9,0
NFC	86,3	18,7
Total starch	84,3	ND
TDN	89,2	53,4

DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, NFC: non-fibrous carbohydrates and TDN: total digestible nutrients; ND: not detected.

Experimental procedure. The materials were chopped separately with an electrical-engine chopper until obtaining an average particle size of 2,5 cm. They were manually mixed with the immature SB fruits. To store the microsilos polyethylene bags for vacuum packing were used, with capacity for 5 kg and diameter of 0,063 mm. The material was manually deposited and compacted. The air was well extracted through an aspirator. After the elimination of oxygen, the bags were sealed with plastic duct tape and were placed inside a bag for silage in a room, protected from the attack of birds or routine works, which could affect the ensiling process.

Sampling and experimental variables. After 40 days of fermentation, from each microsilo a 0,6-kg sample was taken to determine the silage quality. For such purpose the following fermentative indicators were analyzed: pH with a potentiometer with hydrogen electrode through the methodology proposed by the WHO (2003) and lactic acid according to the method indicated in Ball *et al.* (2011) by high production liquid chromatography (HPLC). A sample from each repetition was taken to perform the nutritional composition analyses, in which dry matter (DM), crude protein (CP = N x 6,25), ethereal extract and ash, were determined, according to the methods indicated in AOAC (1998). Non-fibrous carbohydrates (NFC) were estimated according to Detmann and Valadares-Filho (2010).

For the determination of the starch content the method described by Salazar-Murillo and Granados-Chinchilla (2018) was used, with the utilization of HPLC and an Agilent 1260 Infinity chromatograph, with an Agilent Hi-Plex H column. The concentration of neutral detergent fiber (NDF) and lignin were determined through the methodology proposed by Van Soest *et al.* (1991). The digestible neutral detergent fiber (dNDF) and total digestible nutrients were estimated according to the technique described by Detmann *et al.* (2008). The energy fractions were calculated by the equations referred in the requirement tables of NRC (2001) for dairy cattle.

Statistical analysis. The data were tabulated and analyzed through general linear mixed models (GLMM) by the statistical program INFOSTAT® Professional (Di-Rienzo *et al.,* 2019). In addition, regression analysis was carried out to determine the change rate in the nutritional variables, if the treatment effect was significant. From the regression equations the significant slope was used for the estimation of the change rate in each variable. The analysis by Pearson coefficient was also used to find the correlation among all the bromatological variables and the fermentation indicators. In all the conducted analyses significance was declared when $p < 0,05$. Although they were considered trend of the treatment when $p > 0,05$ was obtained; but $<0,1$. For the comparison among means Tukey's test was used, with confidence level of 95 %.

Results and Discussion

Fermentation indicators and dry matter. The DM content showed significant differences ($p < 0,001$) due to the inclusion of SB fruit. It was observed that when SB was included in the mixture there was DM increase as the SB quantity increased. The regression equation for this variable [DM=0,06(x)+19,3] indicated that for every increase of 15 % SB the DM content of the silages increased by 0,9 points. The treatment with 45 % SB was the one that showed higher DM content compared with the level 0 % SB (table 2). In all the analyzed silos presence of effluents was found, without differences among treatments.

The inequalities found among treatments were significant from the statistical point of view. However, they were not significant from the practical perspective, because the difference among treatments was little, and a change in the environmental conditions could modify the dry matter content in the forage, and ultimately in the silage (López-Herrera and Briceño-Arguedas, 2016).

The DM content in the silages could have been defined by the DM concentration present in both materials that make up the silage and by the conservation method used during the experiment. All the silages showed lower contents than 35 % DM, which is to be expected if it is considered that the DM content of the materials used to elaborate the silages was lower (table 1). According to Borreani *et al.* (2018) and Grant and Ferraretto (2018), any material with DM content lower than 35 % can show lower losses due to effluents, which can be leached and reduce the availability of soluble carbohydrates, necessary for the fermentation of lactic acid bacteria. This can affect pH reduction and predispose the development of secondary fermentations produced by other bacteria, which can affect the synthesis and final quantity of lactic acid.

The pH showed significant differences ($p < 0,001$) among treatments. The means were lower as the SB quantity increased. Thus, the treatment with higher pH was 0 % SB; while the one with the lowest pH was 45 % SB (table 2). The regression calculated for this variable [pH=-0,06(x)+6,6] indicated that for each 15 % increase of SB the pH of the silages decreases by 0,9 points. The production of organic acids, mainly lactic acid, causes pH reduction during ensiling (Kung *et al.*, 2001). Nevertheless, it can be affected by the buffering capacity and by the moisture content of the material (Borreani *et al.*, 2018).

As shown in table 2 there were differences among treatments ($p < 0,001$), the 45 % SB being the one that showed the highest concentration of lactic acid; while the treatments with lower acid concentration were 0 and 15 % SB. This performance in the synthesis of lactic acid can be explained from the above-mentioned effects, because the treatments with 0 and 15 % SB were the ones with higher moisture content (table 2), ash and CP (table 3), besides being those with higher pH value.

According to Borreani *et al.* (2018), these factors are associated with the increase of the buffering capacity of forage and with losses during the ensiling process. Thus, the moisture content produces effluents that reduce the availability of soluble carbohydrates. At the same time, there is a forage mixture that has higher buffering capacity, which prevents the adequate reduction of pH (<5,0) in the silo. This situation predisposes the development of secondary fermentations, which reduce the synthesis and concentration of lactic acid increases 2,3 points for every increase of 15 % SB.

Table 2. Dry matter, pH and lactic acid means of the ensiled treatments.

Musa sp.	DM, %	pH	Lactic acid, % DM
0	19,3[a]	6,6[d]	0,3[a]
15	20,2[ab]	5,6[c]	0,7[a]
30	21,1[b]	5,2[b]	2,6[b]
45	22,0[c]	4,1 [a]	7,3[c]
SE ±	0,259	0,048	0,135
P - value	<0,001	<0,001	<0,001

Different letters in the same column are different $p < 0,05$

The above-stated fact was estimated from the regression equation [Lact=0,15(x)-0,68], where the slope was highly significant ($p < 0,001$). Thus, the treatment with 45 % SB was the one with the highest quantity of lactic acid, due to a higher DM content and lower buffering capacity (lower CP and ash), which caused adequate pH decrease and lactic acid production.

This effect of DM and pH on the production of lactic acid is reaffirmed through the calculation of the following correlations: the first one between the DM content and concentration of lactic acid ($\rho= 0,71$ $p=0,002$), and the second between the concentration of lactic acid and pH value ($\rho= -0,90$ $p< 0,001$).

Although the DM concentration in all the treatments was lower than that expected for good silage (< 35%), in all the treatments with 30 and 45 % SB there was a lactic acid production in the expected range for silages or higher (2-4 % DM). This is very favorable, because lactic acid can be transformed into propionic acid in the rumen, as reported by Kung *et al*. (2001). These authors report that in silages with < 30 % DM higher concentrations than 4 % DM in the lactic acid can be reached, as occurs in this research with the treatments with 45 % SB. In this case, the improvement comes from a higher contribution of soluble carbohydrates, because immature SB has a SC content of 6,2 % DM, which is added to the contribution made by molasses and forage to favor fermentation and decrease pH (López-Herrera, 2019).

Intracellular components. Crude protein (CP) showed significant differences ($p < 0,001$), due to the quantity of SB fruit (table 3). The content of this fraction was reduced as the quantity of SB increased. In this case, the regression equation [CP=-0,12(x)+14,2] indicates that the reduction in the protein concentration occurs at a rate of 1,8 percentage points for each 15 % increase in the quantity of SB.

The treatment with higher CP content was the one with 0 % SB; while the treatment with lower concentration was 45 %. These differences are due to the concentration of each of the materials used for the mixture and applied proportions in each treatment. All the treatments showed CP contents higher than 7 % DM, necessary value to prevent deficiencies in the nitrogen metabolism and maintain the adequate functioning of the rumen (Calsamiglia *et al*., 2010), which allows them to be considered adequate for the supplementation of dairy cattle.

When comparing the CP data (tables 1 and 3), it can be estimated that there is 28 % decrease in the CP content, when passing from the fresh to the ensiled state. According to Kung *et al*. (2001), forages with high moisture and protein content, like in the case of *T. gigantea* used in this study, they could be

Table 3. Concentration of intracellular components of the *T. gigantea* silages with *Musa* sp. (% DM).

Musa sp.	CP	NFC	Total starch	Ash
0	14,2[d]	19,7[a]	0,49[a]	28,4[d]
15	12,0[c]	31,5[b]	7,5[b]	22,5[c]
30	10,8[b]	41,7[c]	13,0[c]	19,1[b]
45	8,9 [a]	58,1[d]	23,8[d]	13,8 [a]
SE ±	0,282	1,337	1,140	0,537
P - value	<0,001	<0,001	<0,001	<0,001

Different letters in the same column are different $p<0,05$

exposed to an intense proteolysis process, product from clostridial fermentation. This originates higher concentrations of soluble nitrogen and ammoniacal nitrogen, which generates in the silages lower values of final CP.

The silages showed CP levels comparable to the silages of *Cratylia argente*a (Desv.) O. Kuntze and *Erythrina poeppigiana* (Walp.) O.F. Cook with SB, reported in the study by Montero (2016), and were higher than the ones referred by Alpízar *et al*. (2014) in silages of *Sorghum bicolor* (L.) Moench and *Morus alba* L. These differences are due to the characteristics of each species, as well as to the moisture present in the forage at the moment of ensiling (Grant and Ferraretto, 2018).

The CP showed significant differences ($p < 0,001$), due to the quantity of SB fruit (table 3). The content of this fraction was reduced as the quantity of SB increased. In this case, the regression equation [$CP=-0,12(x)+14,2$] states that the reduction in the protein concentration occurs at a rate of 1,8 percentage points for each 15 % increase in the quantity of SB.

The NFC concentration presented significant differences ($p < 0,001$) due to SB. Thus, at higher quantity of SB the concentration of NFC in the silage was higher, the treatment with 45 % SB being the one that showed higher concentration of this fraction (table 3). The NFC increase occurs, as average, at a rate of 12,2 points for every 15 % increase of SB, when considering that the regression [$NFC=0,81(x)+19,7$] was significant for the estimation of NFCs (table 3). This increase in the NFC concentration is due to two main reasons: higher production of organic acids in the silo and higher quantity of starch from the SB.

According to Detmann and Valadares-Filho (2010), NFCs include simple sugars, starch and organic acids, the last ones being characteristic of the silage biochemistry and necessary for pH decrease (Kung *et al*., 2001). It was determined that there is correlation between the pH value and NFCs ($\rho= -0,97$ $p=<0,001$), as well as between lactic acid and NFCs ($\rho=0,94$ $p < 0,001$). According to this, it could be assumed that in the treatments with better indicators higher quantity of organic acids, which are partial part of NFCs, was generated.

The increase of NFCs also comes from higher utilization of SB in the ensiled mixture, which increases the quantity of added starch. The total starch content showed differences ($p < 0,001$) among the ensiled treatments, with significant increase ($p < 0,001$) of 7,61 points for each 15 % increase of SB, according to the regression equation [$Total\ starch=0,51(x)-0,49$]. The treatment with 45 % SB was the one with the highest content of total starch (table 3). Starch is the main compound in the SB fruits, when immature, according to López-Herrera (2019). Thus, by increasing the quantity of SB, starch increases in silages.

The starch preserved during ensiling can be transformed into propionate in the rumen, for which its increase could influence positively ruminant productivity Owens and Basalan, 2016). It should be considered that there are starch losses during ensiling, because bacterial amylase can remain active, even until day 56 of silage (Ning *et al*., 2017). Nevertheless, it is important to guarantee adequate balance of starch in the diet to prevent rumen acidosis (Humer *et al*., 2018). In this study, all the treatments with SB have less than 34 % starch, value that is lower than the one reported by Ferraretto *et al.* (2018) for *Zea mays* L. silages. Nevertheless, it is higher than that referred by Serbester *et al.* (2015), who worked with silages of *Z. mays* and *Glycine max* (L.) Merr. However, the silages studied here have higher protein content, which turns them into a quality nutritional complement for its use in feeding programs aimed at dairy cattle. The silages must be balanced to prevent the fermentation of large quantities of starch in the rumen, which could predispose to rumen acidosis (Zebeli *et al.,* 2010).

The mineral content (ash) showed significant differences among treatments ($p < 0,001$) when SB was used. The ash content was reduced as the SB quantity increased. The regression equation [$Ash=-0,32(x)+28,4$] indicates that the reduction in the ash concentration occurs at a rate of 4,8 percentage points for every 15 % increase in the SB quantity. Thus, the treatment with 45 % SB was the one that showed lower concentration, for 13,8 % DM (table 3).

The reduction found in the ash content coincides with the results obtained by Rojas-Cordero *et al.* (2020), who reported reduction in the ash when SB is incorporated in the silages. Montero-Durán (2016) indicates that SB has 5 % DM of ash, which explains its capacity to reduce this fraction. On the contrary, Ramsumair *et al*. (2014) state that *T. gigantea* can contain 26,7 % DM in ash, according to the harvest age. For these authors, its mineral contribution is of calcium mainly, which allows to explain the contents found with 0 % SB.

By decreasing the concentration in the ash content, two important effects for the use of these materials as feed complement, are obtained. The first one is related to the improvement in the energy contribution of the silages, because ash lacks such contribution (Carvalho *et al.,* 2016). According to Owens and Basalan (2016), ash reduction increases the quantity of organic matter that is fermented in the rumen, and which contributes energy for animal production (table 4). The second effect is related to the reduction in the buffering capacity of forage, which favors a better conservation of materials in the silo (Borreani *et al*., 2018). In this last case, it was possible to calculate a correlation between pH and ash (ρ=0,97 p=<0,001). The data shown in tables 2 and 3 support this argument. The treatments with lower ash content were the ones that showed better fermentation indicators.

Components of the cell wall and energy. The neutral detergent fiber (NDF) of the silages showed significant differences (p < 0,001) due to the inclusion of SB, the treatment with 45 % SB being the one that showed the lowest NDF content compared with 0 %, which had the highest concentration (table 4). The reduction of NDF occurs, as average, at a rate of 5,7 points for every 15 % increase of SB. The linear regression [NDF=-0,38(x)+36,4] was significant (p < 0,001) for the estimation of NDF (table 4).

The NDF reduction is a trend that has been reported in other studies (Rojas-Cordero *et al.,* 2020). This reduction is favorable for the ruminant, because it has been observed that high quantities of NDF reduce voluntary intake, which is due to physical filling that causes the distension of the rumen walls (Sousa, 2017). Thus, it is to be expected that, by using this silages as feed complement, DM intake is stimulated. Nevertheless, they should be considered as complement and not as the basis in a diet, because they have low NDF contents, with moderate quantity of starch, especially in the treatments with 30 % and 45 % SB. This could affect rumination, if the intake of physically effective fiber is not balanced (Banakar *et al.,* 2018).

Lignin also showed significant differences (p < 0,001) among treatments. This compound decreased as the quantity of SB increased, so that the treatment with 45 % SB was the one that showed the lowest concentration of lignin. The regression calculated to estimate the reduction of lignin was significant (p < 0,001). Through the equation [Lignin=-0,13(x)+9,9] it could be detected that this compound decreases, as average, at a rate of 1,9 points for every increase of 15 % SB. The decrease in the lignin content is caused by the concentration of this compound in SB. This performance agrees with the work conducted by Montero-Durán (2016), although it is opposed to the one referred by López *et al.* (2017). In both cases, this is due to the differences shown by the forages used in this compound.

The lignin contents determined in this study were higher than those obtained by Roa and Galeano (2015), although lower than the ones reported by Ramsumair *et al.* (2014). This suggests that the forage used could have been harvested at different ages or heights than the one used in the above-cited studies. These differences are important, because the quantity of lignin has been related to the digestibility of other cell wall components (Banakar *et al.,* 2018). According to Combs (2014), the fiber digestibility has higher impact on animal productivity, if it is compared with the digestibility of any other nutrient.

Regarding the above-explained facts, Detmann *et al.* (2008) state that dNDF depends on the concentration of total fiber, concentration of total lignin and relation of both in the material. Because of this, although it is possible to detect significant differences (p < 0,001) in the dNDF, with a trend

Table 4. Concentration of the cell wall components and energy of *T. gigantea* silages with *Musa* sp.

Musa sp.	NDF, %	dNDF, %	Lignin, %	TDN, %	NE_L, Mcal/kg DM
0	36,4^{d}	19,3^{d}	9,9^{c}	45,2^{a}	1,0^{a}
15	31,5^{c}	17,3^{c}	8,5^{c}	52,4^{b}	1,2^{b}
30	26,9^{b}	14,9^{b}	6,4^{b}	58,9^{c}	1,3^{c}
45	17,5 ^{a}	10,1^{a}	3,2 ^{a}	68,5^{d}	1,6^{d}
SE ±	0,792	0,446	0,275	0,802	0,020
P - value	<0,001	<0,001	<0,001	<0,001	<0,001

NDF: neutral detergent fiber, dNDF: digestibility of neutral detergent fiber, TDN: total digestible nutrients, NE_L= net lactation energy
Different letters in the same column are different (p < 0,05)

to decrease the dNDF as the quantity of SB in the silage increases, it was not possible to find significant differences or trends in the dNDF [(dNDF/NDF) x 100)]. This means that the quality of NDF in the treatments is similar. However, as has been previously indicated, when using these materials they should be balanced with other feeding resources that promote the intake of physically effective fiber and prevent the affectation of rumination.

The energy content in the form of TDN or net lactation energy (NE_L) showed significant differences ($p < 0,001$) among the treatments. It was determined that the energy content was influenced directly by the quantity of SB in the silages, so that the treatment with 45 % SB was the most energetic one. The calculated regressions [TDN=-0,5(x)+45,2] and [NE_L=-0,01(x)+0,99] were significant ($p < 0,001$) and allowed to estimate that the increase in the energy content occurs at a rate of 7,5 points of TDN and 0,15 Mcal of NE_L, for every 15 % increase of SB.

The increase in the energy content of the silages is due to the increase in the SB quantity that was used. The fruits have higher energy concentration compared with *T. gigantea* (table 1). This performance is similar to the one determined in other studies, in which SB was used as additive for silage (Montero-Durán, 2016; López *et al.,* 2019). And this is due to the fact that that substitution is made of forage resources by SB with higher energy (89,2 % TDN).

In spite of the energy increase of the treatments with 15 % and 0 % SB showed lower value than the *Zea mays* L.- *Glycine max* (L.) Merr. silages studied by Serbester *et al.* (2015), although their protein content was higher. Meanwhile, the treatments with 30 and 45 % SB showed similar energy content as the silages reported by Serbester *et al.* (2015), with protein levels comparable among them. This allows to consider the silages with SB as an effective alternative for the supplementation of dairy cattle.

Conclusions

Musa sp. proved to be an additive with capacity to improve the process of *T. gigantea* forage conservation, with more favorable indicators, because it supposes increase in the dry matter and non-fibrous carbohydrates of the silage, especially at higher levels than 30 %. The mixtures showed adequate nutritional characteristics for their utilization as feeding complement in balanced diets for ruminants. The conduction of studies at higher scale, which involve the analysis of animal performance and productivity, is suggested.

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Conflicts of interests

The authors declare that there is no conflict of interests among them.

Authors' contribution

- Daniel Rojas-Cordero. Conducted the experiments in the field, design and setting up of the experiments, data collection and processing, as well as manuscript writing and revision.
- Andrés Alpízar-Naranjo. Conducted the experiments in the field, design and setting up of the experiments, data collection and processing, as well as manuscript writing and revision.
- Miguel Ángel Castillo-Umaña. Conducted the experiments in the field, design and setting up of the experiments, data collection and processing, as well as manuscript writing and revision.
- Michael López-Herrera. Conducted the experiments in the field, design and setting up of the experiments, data collection and processing, as well as manuscript writing and revision.

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