Scientific Paper

Effect of harvest age on the digestibility and energy fractioning of two forage shrubs in Colombia

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Abstract

Objective: To evaluate the effect of harvest age and season on the chemical composition, with emphasis on the energy fractioning and digestibility of *Tithonia diversifolia* (Hemsl.) A. Gray and *Sambucus nigra* L, established in a silvopastoral system in the Pasto region, Nariño, Colombia.

Materials and Methods: The study was conducted at the Obonuco Research Center of AGROSAVIA, Pasto, from January to November, 2018. A randomized block design was used, with three replicas and two treatments, associated to the factor cutting age for each species (*T. diversifolia*, 60 and 80 days and *S. nigra*, 60 and 90 days). For the study of the variables two seasons were differentiated: high and low rainfall. Yield and nutritional variables were evaluated, with emphasis on the energy value (digestible energy, metabolizable energy and net lactation energy). The software R V. 3.5.1 was used for the statistical processing. Variance analysis and Tukey's mean comparison test, for $p < 0,05$, were applied.

Results: The highest digestibility values (79,3 and 77,8 %), digestible energy (3,93 and 3,32 Mcal/kg DM), metabolizable energy (2,8 and 2,7 Mcal/kg DM) and net lactation energy (1,67 and 1,63 Mcal/kg DM) appeared at the age of 60 days, in the rainy season for T. diversifolia and S. nigra, respectively. With regards to the biomass production, for *T. diversifolia* the dry matter yield increased significantly ($p < 0,05$) with age, in the two seasons, and for *S. nigra* in the dry season.

Conclusions: The values at higher ages (80 and 90 days) were considered acceptable, which proved the potential of these forage plants to improve the nutritional quality of diets in animal husbandry systems.

Keywords: *Sambucus nigra*, silvopastoral system, *Tithonia diversifolia*, nutritional value

Introduction

The conventional management of animal husbandry systems, along with the effects of climate change, has affected their productivity, profitability and resilience; besides being related to negative environmental effects (López-Vigoa *et al*., 2017).

In the face of this reality, the need emerges to lead this productive field towards sustainable development. From this perspective, silvopastoral systems constitute one of the potential alternatives. With this type of system, by the incorporation of trees and shrubs, as productive components of pasturelands, to contribute to the improvement of the nutritional offer, to animal welfare, and to conservation of natural resources is sought (Arciniegas and Flórez, 2018).

In the cattle husbandry of the Colombian high tropic, forage from pastures is the basis of feeding systems. Nevertheless, one of the main limitations of these productive systems is the use of pastures in monoculture. These pastures do not contribute sufficient nutrient availability, in quantity as well as quality, to cover animal requirements, which affects the success of the system productivity (Enciso *et al*., 2018).

Prevailing species such as kikuyu [*Cenchrus clandestinus* (Hochst). ex Chiov.] show unbalances in their nutritional value (Flórez-Gómez y Correa, 2017), because they generally have high crude protein contents (> 16 %) and energy content from moderate to low (Vargas-Martínez *et al.,* 2018a). In addition, in the Colombian high tropic, forage seasonality is evident, caused by marked periods of rains and intense summers. This climate variability has negative incidence on the nutrient availability of forages (Castro-Rincón *et al*., 2019).

This is in addition to the inadequate management of the cutting intervals of forages, over the optimum harvest ages, which causes increase in fiber contents, at the expense of the reduction of nutrients, such as protein and energy, and decrease of digestibility (Flórez-Gómez and Correa, 2017;

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Vargas-Martínez *et al.,* 2018a). This decrease of the energy contribution significantly affects the productive and reproductive response of the animals, besides increasing the excretion of nitrogen compounds to the environment (Vargas-Martínez *et al*., 2018a).

Parallel to the improvement of management, it is also important to explore new forage resources with high digestibility, which improve the energy-protein balance in the diet of ruminants and that, in turn, decrease the excretion of contaminating compounds (Carulla and Ortega, 2016).

The study of the optimum harvest ages, as well as the evaluation of the introduction and use of woody shrub species in animal husbandry systems, such as *Tithonia diversifolia* (Hemsl.) A. Gray (*Mexican sunflower*) and *Sambucus nigra* L (elder, black elder, elderberry), could be a strategy to improve the energy contribution, maximize the use of protein and increase digestibility in the diet of grazing ruminants (Cardona *et al*., 2019)..

The objective of this study was to evaluate the effect of harvest age and season on the chemical composition, with emphasis on the energy fractioning and digestibility of *T. diversifolia* and *S. nigra*, established in a silvopastoral system in the Pasto region, Nariño, Colombia.

Materials and Methods

Location and soil. The experiment was conducted from January to November, 2018, on an andisol soil, of loamy-sandy texture, at the Obonuco Research Center, belonging to the Colombian Corporation of Agricultural Research (AGROSAVIA). This facility is located at 2 750 m.a.s.l., between the coordinates 1°11'41,3'' N and 77°19'19"W, in the Pasto municipality, Nariño department.

Climate conditions. The zone shows average temperature of 12,8 ºC, relative humidity of 84,4 % and annual average rainfall of 619,8 mm. In the dry season it records approximately 255,7 mm, and in the rainy season, 404,8 mm (according to automatic climate station Davis Vantage pro2 Agrosavia- Obonuco). During the experiment, the distribution of rainfall was bimodal, with two dry periods (January-February and July-August) and two rainy periods (March-May and September-November).

Experimental design and treatment. A complete randomized block design was applied, with three replicas and two treatments per species (*T. diversifolia* and *S. nigra*), resulting from two cutting ages: 60 and 80 days in *T. diversifolia*; 60 and 90 days in *S. nigra*. For the performance analysis, two seasons were differentiated: rainy and dry season. Each experimental unit was made up by six shrubs, and was separated from the next treatment by a row of shrubs that were not evaluated, in order to control the edge effect (table 1).

In *S. nigra* different frequency was used, because previous experiments conducted at the Research Center proved that this species requires a longer recovery time, due to its regrowth capacity, with regards to *T. diversifolia*. This cutting age was also taken from reports of other studies, such as the one conducted by Cárdenas *et al*. (2016).

Experimental procedure. The research was conducted in a forage bank, composed by the species *T. diversifolia* and *S. nigra*, with one year and a half of establishment. They were sown at 1 x 1 m, in blocks, with a total of 102 shrubs (per species). At the beginning of the experiment, a homogenization cut was made, at 50 cm of height over the soil level (Ekeocha, 2012).

Afterwards, to determine the production of green forage, taking into consideration the experimental treatments, the leaves and fresh stems were manually harvested, at 50 cm of height with regards to the soil. Four cuts (cycles) were performed in total during 11 months, for each of the treatments per species: two in the rainy season (RS) and two in the dry season (DS), from January to December, 2018.

The agronomic management of the system was carried out through weed and pest control, as well as the preventive application of organic insecticide. According to the soil analysis, fertilization was applied after each cutting cycle, with 250 g of organic fertilizer and 30 g of chemical mixture (urea, KCl and DAP) per plant.

Evaluated variables. In order to estimate dry matter (DM) kg/shrub, a forage sample of 500 g per treatment in each cutting was taken. It was dried at 70 ºC during 48 h until reaching a constant weight

Table 1. Experimental treatments, according to the study design

T. diversifolia	*S. nigra*
T1: 60 days of cutting	T1: 60 days of cutting
T2: 80 days of cutting	T2: 90 days of cutting

(Téllez and Mendoza, 2014). These data were projected to the yield in tons of DM/ha.

To determine the forage quality, nutritional composition analyses were done in the animal nutrition laboratory of the Tibaitata Research Center of Agrosavia (Bogotá, Colombia) through the application of the Near Infrared Spectroscopy NIRS methodology (Ariza-Nieto *et al*., 2017) with NIRS DS 2500-FOSS Analytical +6A/S equipment, Denmark. The percentage of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), calcium (Ca), phosphorus (P) and total digestible nutrients (TDN), were determined, as well as DM digestibility (%) and the energy fractions (Mcal per kg DM): digestible energy (DE), metabolizable energy (ME) and net lactation energy (NLE).

Statistical analysis. The data were analyzed according to their variance and normal distribution. Afterwards, a variance analysis was done to determine significance and the means were compared through Tukey's test (α =0,05). This process was carried out with the statistical program R. V.3.5.1 (R Development Core Team, 2008), besides the packages CAR (Fox and Weisberg, 2011) and AGRICOLAE (Mendiburu, 2017).

Results and Discussion

The yield and nutritional composition for *T. diversifolia*, at different cutting ages and seasons are shown in table 2.

In turn, the yield and nutritional composition for *S. nigra*, at different cutting ages and seasons, are shown in table 3.

Regarding biomass production, in this research, the yield of DM t/ha was significantly increased ($p < 0,05$) with the age in the two seasons, for *T. diversifolia*, and in the DS, for *S. nigra*.

This performance is similar to the one reported by Cárdenas *et al*. (2016) in these species, when the harvest age was higher than 80 days. These authors found, as average, values of 3,3 and 1,3 kg/shrub for *T. diversifolia* and *S. nigra*, respectively.

The DM content in *T. diversifolia* significantly increased ($p < 0,05$) at higher cutting age (60 *vs* 80 days) in the RS (12,0 *vs* 15,6 %, respectively) as well as in the DS (17,0 *vs* 20,2 % respectively). This performance agrees with the report by Pérez *et al*. (2009) for this species, who recorded 14,1; 17,3 and 23,3 % DM, at 30, 60 and 89 days of harvest, respectively.

The CP content showed effect of the harvest age ($p < 0,05$), being lower as the cutting age increased. For *T. diversifolia* in the RS, the CP values decreased from 32,0 to 22,7 % when the cutting frequency increased, from 60 to 80 days. Meanwhile, in the DS, the decrease was from 24,1 % to 19,7 %, respectively. The CP results in this species are in correspondence with those reported by Lezcano *et al*. (2012), who found values of 29,8 % in plants of 30 days, with regards to the ones harvested at 60 days (22,0 %). Nevertheless, it is important to emphasize that, in this research, the pants with 60 days of age showed protein contents higher than 30 %.

Similar performance was recorded in *S. nigra*. In the plants from 60 to 90 days of cutting, the CP values decreased in 7,9 % in the RS. Regarding *S. nigra*, Barreto and Chamorro (2005), in the Colombian high tropic, reported CP values of 30,2; 30,9; 29,4 and 29,6 %, at the ages of 40, 60, 70 and 80 days after cutting, respectively; results that surpass the ones in

Table 2. Yield and nutritional composition of *T. diversifolia,* at different cutting ages, in the high and rainy season

Indicator	Rainy season			Dry season		
	60 days	80 days	SE ±	60 days	80 days	SE ±
GF, kg/shrub	3,5	7,2	0,723**	1,1	2,6	0,521*
DM, %	12,0	15,6	0,652***	17,0	20,2	0,732**
DM, t/ha	4,2	11,1	1,233***	1,9	4,9	0,945*
CP, %	32,0	22,7	1,245***	24,1	19,7	1,013***
NDF, %	31,5	34,8	0,656**	35,0	39,3	0,823***
ADF, %	15,6	16,6	0,637	18,0	17,9	0,423
TDN, %	72,7	66,4	0,913***	66,5	64,6	0,756*
Ca, %	0,9	0,8	0,001*	0,8	0,6	0,434*
P, %	0,3	0,2	0,004**	0,3	0,3	0,012

***p ≤ 0,001; **p ≤ 0,01; *p ≤ 0,05

Table 3. Yield and nutritional composition of *S. nigra*, at different cutting ages, in the rainy and dry seasons

Indicator	Rainy season			Dry season		
	60 days	90 days	SE ±	60 days	90 days	SE ±
GF, kg/shrub	1,5	3,0	0,456*	0,7	1,5	0,213*
DM, %	22,4	18,2	0,723	16,2	18,7	0,543*
DM, t/ha	3,3	5,5	0,923	1,2	2,8	0,465*
CP, %	28,1	20,2	1,123***	26,3	20,3	1,242***
NDF, %	28,1	30,2	0,854**	31,0	29,0	0,634
ADF, %	13,8	13,0	0,423	8,0	15,2	0,956
TDN, %	71,3	65,3	0,732***	70,0	64,8	0,934***
Ca, %	0,7	0,8	0,032**	0,7	0,8	0,125
P, %	0,3	0,2	0,012**	0,2	0,1	0,145***

***p ≤ 0,001; **p ≤ 0,01; *p ≤ 0,05

this experiment. Nevertheless, it was proven that after 60 days the CP percentage decreases.

According to the observations made in this study, for both species, independently from the cutting age and harvest season, the CP value is higher than that reported in basis grasses in livestock feeding systems in the Colombian high tropic. This is the case of *C. clandestinus* (kikuyu), for which average values of 20 % are reported, with 45 days of rotation (Vargas-Martínez *et al*., 2018a; Cardona *et al*., 2019).

Fiber levels in the diet of ruminants are an estimation of the age and chemical composition of the offered forage (Castro-Rincón *et al*., 2019). The NRC (2001) recommends for diets of dairy cows a minimum content of 25 and 17 % (on dry basis) of NDF and ADF, respectively, in order to stimulate rumination and maintain good rumen functioning.

In this study, the values for these fractions were relatively low, for which they show potential to stimulate the adequate rumen functioning, if it is taken into consideration that the inclusion of such fractions in the diet of ruminants would be complemented with grazing and other forages, in general, effect of the harvest ages for the NDF was observed, for *T. diversifolia* and *S. nigra*. This fraction increased ($p < 0,05$), as the harvest age increased.

The TDN contents were also affected by the cutting frequency. The 60-day interval propitiated the highest values, in *T. diversifolia* as well as in *S. nigra*, for the RS and the DS. Thus, in *T. diversifolia* values of 69,6 and 66,5 % were found, at 60 and 80 days of harvest; while in *S. nigra* they were 70,6 and 65,1 %, and 60 and 90 days, respectively.

These contents are higher than those reported for the above-mentioned grasses (kikuyu 60 % as average, 45 days of harvest; cultivated perennial ryegrasses 63 % as average and 35 days of harvest), and coincide with the ones referred by Vargas-Martínez *et al.* (2018b), and Castro-Rincón *et al.* (2019), respectively. High contents of TDN in forages are generally related to good digestibility and energy contents in the diet (Sanabria-Celis and Ávila-Carrillo, 2015). At nutritional level, this could mean a potential in the energy contribution of these two perennial forage plants.

For the case of minerals, Ca in *T. diversifolia* showed significant decrease ($P < 0,05$), as the harvest age increased for both cutting seasons (RS and DS). Contents of 0,9 and 0,8 %, respectively, were found, at the age of 60 days, and contents of 0,8 and 0,6 %, respectively, for 80 days. Several authors recorded Ca values between 0,9 and 2,86 % for *T. diversifolia*, with the highest content between 55 and 70 days of cutting (Gallego-Castro *et al*., 2017; Londoño *et al*., 2019).

The performance of Ca in *S. nigra* was different in the RS, because at higher harvest age increase of this mineral was observed ($p < 0,05$), with contents of 0,7 and 0,8 % for the ages of 60 and 90 days, respectively. P showed a similar performance for both species. Its contents decreased ($p < 0,05$) as the harvest age increased. It is important to emphasize that at 90 days in the DS there were very low P contents.

The deficiency of P in tree forages has been reported in other studies, which suggest that it can be affected by the low level of P in the soil, as well as by the plant age and the dry season (Sánchez-Gutiérrez

and Faría-Mármol, 2008). In *T. diversifolia* values of P are reported between 0,3 and 0,4 % (Londoño *et al*., 2019), similar to the ones in this study.

According to Sánchez-Gutiérrez and Faría-Mármol (2008), there is high content of minerals in the plant during the initial stages of growth and gradual dilution, as the plant matures and accumulates carbon hydrates, which explains the decreases that appeared in most cases with the increase of harvest age. In general, both forage species are characterized by their good contributions of Ca and P, which are higher than those of the traditional pastures of the high tropic (Londoño *et al*., 2019; Fonseca *et al*., 2019).

The energy and digestibility values for *T. diversifolia* and *S. nigra* are shown in tables 4 and 5. They present the percentage of DE, ME, and NLE in Mcal/kg DM at different ages and cutting seasons.

Digestibility decreased ($p < 0,05$) as the cutting age increased in both forage plants, in the RS as well as the DS. When harvesting *T. diversifolia*, at the age of 80 days, there was decrease of digestibility by 6,7 and 5,5 %, with regards to 60 days of cutting, for the RS and DS, respectively. In the case of *S. nigra*, when harvesting at 90 days, its digestibility decreased by 6,4 and 5,5 compared with the plants evaluated at 60 days, for the RS and DS, respectively. Just like in this study, Guatusmal *et al.* (2020) found decrease of digestibility in *T. diversifolia* and *S. nigra* plants, as the harvest age increased, which according to these authors was due to the lignification of the cell wall, which increases with age.

In this work there was increase ($p < 0,05$) of NDF at 60 days for *T. diversifolia*, with regards to 80 days for both seasons; while the ADF remained similar. For *S. nigra*, difference was shown ($p < 0,05$) in the NDF values, lower at 60 days, compared with 90 days of harvest in the RS. The ADF was higher ($p < 0,05$) at the harvest age of 90 days in the RS (tables 4 and 5). These results are similar to those referred by Barahona-Rosales and Sánchez-Pinzón (2005) and Chiphwanya *et al.* (2017). According to these authors, the DM digestibility in the forages is, in general, inversely related to the NDF and ADF content.

It can be stated that the use of perennial forage plants, such as *T. diversifolia* and *S. nigra*, favors the forage acceptability, due to its good palatability and high DM digestibility, which generally exceeds 70 %, as shown in this experiment. According to the report by Tarazona *et al.* (2012), these aspects promote DM intake, nutrient flow and balance in the animal. In this sense, maximizing the DM intake in ruminants is an important element in the nutritional field. The nutritional status and productivity of the animals depend on it (Gordon and Prins, 2008). Nevertheless, one of the highest limitations to achieve

Table 4. Energy and digestibility value of *T. diversifolia* at different cutting ages per season

Indicator	Rainy season			Dry season		
	60 days	80 days	SE ±	60 days	80 days	SE ±
Digestibility DM, %	79,3	72,6	1,143***	72,6	70,6	0,723*
DEr, Mcal/kgDM	3,9	2,9	0,154***	3,0	2,8	0,032**
MEr, Mcal/kgDM	2,8	2,5	0,044***	2,5	2,4	0,025*
NLEr, Mcal/kgDM	1,7	1,5	0,021***	1,5	1,4	0,017*

***p ≤ 0,001; **p ≤ 0,01; *p ≤ 0,05

DEr: digestible energy for ruminants, MEr: metabolizable energy for ruminants, NLEr: net lactation energy for ruminants, DM: dry matter

Table 5. Energy and digestibility value of *S. nigra* at different cutting ages, in the rainy and dry season.

Indicator	Rainy season			Dry season		
	60 days	90 days	SE ±	60 days	90 days	SE ±
Digestibility DM, %	77,8	71,4	0,758***	76,3	70,8	1,032***
DEr-Mcal/kgDM	3,3	2,9	0,127***	3,2	2,9	0,157***
MEr-Mcal/kgDM	2,7	2,4	0,132***	2,6	2,4	0,156***
NLEr-Mcal/kgDM	1,6	1,4	0,154***	1,6 a	1,5 b	0,126***

***p ≤ 0,001; **p ≤ 0,01; *p ≤ 0,05

DEr: digestible energy for ruminants, MEr: metabolizable energy for ruminants, NLEr: net lactation energy for ruminants, DM: dry matter

an optimum increase of DMI in animal husbandry systems of the tropic, is the low DM digestibility in pastures (Barahona-Rosales and Sánchez-Pinzón, 2005). The above-stated facts are generally due to aspects inherent to the cell wall composition and structure of pastures with regards to the legumes and other forage resources of the tropic (Marais, 2001).

Effect of the harvest age ($p < 0,05$) was shown in the values of energy fractioning for both forages (tables 4 and 5). In general, higher values were observed for DEr, MEr, y NLEr, at the age of 60 days in *T. diversifolia* as well as in *S. nigra*. The energy fractioning values found in this study for both species, independently from the cutting season, were higher than those reported for some forage resources used in the tropic. González-Guarin (2016), in the high tropic of Colombia, recorded 2,38 Mcal/kg DM of DEr for the species *S. nigra*, at 90 days being evaluated, in the RS. This value is lower than the 2,98 Mcal found in *S. nigra* in this experiment.

According to Mendoza-Martínez *et al.* (2008), the forages with high values of DEr are related to low energy losses in solid dejections. This could grant the animal husbandry systems that use *T. diversifolia* and. *S nigra* lower energy cost in feces production.

The MEr found in both species decreased ($p < 0,05$) as the cutting age increased (tables 4 and 5). Regarding the values of MEr found at 60 days for both species, they are higher than those of cultivated pasturelands of *Lolium perenne* L (2,45 Mcal/kg/DM), with36 days of regrowth (Villalobos and Arce, 2014).

The average NLEr, in both harvest seasons, was 1,6 and 1,5 in *T. diversifolia* for 60 and 80 days of cutting, and of 1,61 and 1,5 Mcal/kg DM in *S. nigra* at the ages of 60 and 90 days, respectively. These values are in the range of the report by Guatusmal *et al*. (2020), who refer values of 1,58 and 1,6 Mcal/kg DM of NLE, for *T. diversifolia* and *S. nigra* (60 days of age), respectively.

According to the NRC (2001), the highest limitation of tropical pastures to sustain milk production is energy. Thus, the use of forage resources with energy potential, such as perennial forage plants from silvopastoral systems, could be a valid strategy to improve nutrition and maximize the productivity of animal husbandry systems in the tropic (Cuartas *et al*., 2013).

Conclusions

In this work good energy contribution from the fractions contained in the forage plants, high digestibility values and good balance of the other nutrients, were shown, for which the use of these plants could constitute an adequate strategy to face forage scarcity, as consequence of the climate change.

Such species as *T. diversifolia* and *S. nigra* could serve as nutritional alternative in animal husbandry systems, due to their good availability and to the energy-protein balance in the diet of ruminants. To conduct more studies in order to determine the optimum cutting age in these species, is recommended, aiming at balancing their nutritional content and the forage availability.

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Authors' contribution

- Juan Leonardo Cardona-Iglesias. Conception of the research idea, bibliographic search, manuscript writing, revision and correction.
- Laura Dayana Escobar-Pachajoa. Organization of the research idea, experiment design and setting up, as well as data taking and processing, bibliographic search, manuscript writing and correction.
- Carolina Guatusmal-Gelpud. Organization of the research idea, experiment design and setting up, as well as data taking and processing, bibliographic search, manuscript writing and correction.
- Diego Hernán Meneses-Buitrago. Experiment design and setting up, data taking and processing (statistical analysis), manuscript writing and correction.
- Edwin Castro-Rincón. Experiment design, research advisory, manuscript writing and correction.
- Lina Marcela Ríos-Peña. Data taking and processing, bibliographic search, manuscript writing and correction.

Conflict of interests

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

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