Scientific Paper

Nutritional quality of mixed silages of *Saccharum officinarum* L. and leaves from *Manihot esculenta* Crantz

Ángela María Burgos[1] https://orcid.org/0000-0002-1867-4471, *Miriam Porta*[2] https://orcid.org/0000-0003-2199-9434, *Claudina María Hack*[2] https://orcid.org/0000-0003-2149-6204?lang=es and *María Elena Castelan*[2] https://orcid.org/0000-0003-4684-9539

[1]*Cátedra Cultivos III, Departamento de Producción Vegetal, Facultad de Ciencias Agrarias, Universidad Nacional del Nordeste, Corrientes, Capital, Argentina.* [2]*Instituto Agrotécnico, Facultad de Ciencias Agrarias, Universidad Nacional del Nordeste. Resistencia, Chaco, Argentina.*
E-mail: burgosangela@agr.unne.edu.ar

Abstract

Objective: To evaluate the inclusion of different proportions of leaves from *Manihot esculenta* Crantz in the nutritional quality of *Sacharum officinarum* L. silages in Argentina.

Materials and Methods: A complete randomized design and three replicas per treatment were used: T1) *M. esculenta* (30 %): *S. officinarum* (70 %); T2) *M. esculenta* (50 %): *S. officinarum* (50 %) and T3) *M. esculenta* (70 %): *S. officinarum* (30 %). At 60 days of the silage the percentage content of dry matter, crude protein, acid detergent fiber, phosphorus, calcium, potassium and magnesium, was determined. Digestibility by formula, total digestible nutrients and digestible energy, were estimated. The organoleptic and pH characteristics were determined. A variance analysis and Tukey's test at 0,05 % were used for the separation of means among treatments.

Results: The crude protein had values between 8,4 (T1) and 16,0 % (T3). The aggregation of 70,0 % of *M. esculenta* leaves in the mixture increased the protein value in 90,0 and 25,5 % with regards to treatments T1 and T2. The acid detergent fiber was lower in T3 and, consequently, digestibility and total digestible nutrients increased in this treatment compared with the others.

Conclusions: The inclusion of *M. esculenta* leaves improved the nutritional quality of the *S. officinarum* silage, by increasing, proportionally and significantly, the protein values, digestibility and total digestible nutrients. The ensiled material showed an adequate conservation process.

Keywords: microsilos, chemical composition, nutritional value, supplementation, forage

Introduction

Ruminant feeding in the subtropics is mainly based on the utilization of native pastures as the main source of nutrients (López-Herrera *et al*., 2017). Nevertheless, their yield and nutritional composition is variable, depending on such factors as the cultivar, physiological age (Elizondo-Salazar, 2017) and seasonal conditions (Ramírez-de-la-Ribera *et al*., 2017). In this region, the insufficient quantity and poor nutritional quality of forages stand out, which is mainly due to their low nitrogen contents. Particularly, pasturelands of the Argentinean northeast are characterized by their little quality, because they have low protein percentage, high content of lignified almost indigestible cell wall, and marked deficit of soluble carbohydrates (Burgos *et al.,* 2019). This is in addition to the fact that forage production throughout the year is not constant, and is conditioned by seasonal environmental factors. In spring and summer, the forage resource is abundant and has good nutritional value, but during the winter it has lower quality and scarce quantity (Porta *et al.,* 2020).

This reduction of production during the winter is commonly known as winter gap, situation that reduces the reproductive and productive capacity of cattle. That is why the use of supplements is recommended to prevent, through an adequate supply of energy and protein nutrients, losses in the body condition of the animals and, in extreme cases, death, because when protein is contributed in inadequate quantities animal husbandry production is disfavored (Tagliapietra *et al.,* 2019).

The high-price balanced supplements represent a high percentage of the production costs of the zone (Fernández-Gálvez *et al*., 2018). This situation forces to search for technological alternatives to reduce costs and increase the efficiency of animal husbandry systems (Rojas-Cordero *et al.,* 2020). Taking into consideration that concentrate protein sources are costly, work has been done on the search for alternatives that are economical and viable, such as silages. The elaboration of silages, without causing large transformations in the nutritional quality, allows to preserve the forage

Received: March 14, 2021
Accepted: May 26, 2021

How to cite a paper: Burgos, Ángela María; Porta, Miriam; Hack, Claudina María & Castelan, María Elena Nutritional quality of mixed silages of *Saccharum officinarum* L. and leaves from *Manihot esculenta* Crantz. *Pastos y Forrajes*. 44:eI15, 2021.

excess produced during the spring-summer season, for its utilization in ruminant feeding during the period of lower availability (López Herrera *et al.,* 2017; López Herrera and Briceño-Arguedas, 2017; Rojas-Cordero *et al.,* 2020).

Animal production systems, which include trees and shrubs, are better than those based only on grasses, because their foliage provides higher protein content compared with most pastures. These plants can be cultivated by ranchers in small or large farms (Cardona-Iglesias *et al.,* 2017). Nevertheless, if this type of resource is utilized, the diet should be complemented with energy sources that optimize the utilization of forage nutrients.

In Argentina the production of *Manihot esculenta* Crantz is exclusively aimed at the roots, which are destined for the industry or fresh consumption on table, and the aerial part is wasted, which represents 50 % of the total weight of the plant (Burgos, 2018). For the northeast of the country, the utilization of cassava leaves with forage purposes is proposed as a sustainable solution. They have a crude protein content close to 22,7 % (on dry basis), for which they could go from being a byproduct of root obtainment of the species, to be a derivative of high added value and of high nutritional value (Gil-Llanos, 2015). In fact, the use of cassava leaves has been disseminated in other countries of Latin America, mainly in Colombia and Brazil, being transformed into products that have an added value in origin.

In the sugarcane basin of northeast Argentina, *Saccharum officinarum* L. shows average yield of 40 t GM ha^{-1} $cutting^{-1}$, and is an ideal material to be preserved, due to its high concentration of soluble sugars, although their nutritional quality is limited by their low protein content (≤ 3 % CP). When it is combined with other forages and feed ingredients, *S. officinarum* represents a low-cost and more efficient nutritional option in animal production (Fernández-Gálvez *et al.,* 2018).

The objective of this research was to evaluate the effect of the inclusion of different proportions of *M. esculenta* leaves in *S. officinarum* silages in Argentina.

Materials and Methods

Location. The research was conducted between May and July, 2018, in northwest Corrientes province (27º28'27.23''S; 58º47'00.6''W; altitude of 50 m.a.s.l.), located in northeast Argentina. This province is ranked fourth in animal production at national level, with a stock of 4,7 million heads, where 60 % of all the farmers has less than 100 heads and cattle occupies, approximately, 6,3 million hectares (Ministerio de Producción, 2019). The experimentation site was located in the Experimental Field of the School of Agricultural Sciences of the National University of the Northeast.

Climate characteristics. The climate of the zone shows annual average rainfall of 1 300 mm, and annual mean temperature of 21,6 ºC. The frost-free period is 340 to 360 days per year and their occurrence frequency is 0,5. According to the modified Köppen classification is humid mesothermal, designated as Cf w'a (h) (Murphy, 2008).

Soil characteristics. The soil is sandy, classified as *Updipsammentes argic*, mixed hyperthermic family. It shows thick granulometry on surface and is moderately to weakly acid in horizon A (Escobar *et al.,* 1994). They are soils of low fertility, low cation exchange capacity, but with good physical conditions for the cultivation of *M. esculenta* and *S. officinarum*, associated to their sandy texture.

Treatments and experimental design. The utilized design was complete randomized, with three treatments and three repetitions (table 1).

Table 1. Proportion (p:p) of *M. esculenta* leaves and *S. officinarum* stems used in each treatment.

Treatment	*M. esculenta*, %	*S. officinarum,* %
1	30	70
2	50	50
3	70	30

Agronomic management of the forages. The plantation of *S. officinarum* var. fam 81-77 was in its third year of implantation. Planting was done in simple rows, at a distance of 1,60 m. Fertilization was performed with urea at a rate of 100 kg per hectare and per year, and did not receive irrigation. The weeds were mechanically controlled, with furrowers mounted on the three spots of the tractor. The *S. officinarum* stems were harvested in the maturation phase during May.

M. esculenta (cv. Palomita) was sown in September, 2017, at density of 10 000 plants ha^{-1}, because they were aimed at root production. At the moment of harvest, it had been established for 8 months.

From the cultivated plots of each species, all the plants that formed a composite sample were harvested, of which the necessary quantities of

M. esculenta leaves and *S. officinarum* stems, respectively, were taken, to elaborate the silos of each treatment.

For the elaboration of the silos all the leaves of each *M. esculenta* plant (basal, intermediate and apical) were used, which were manually separated from the stems, with the aid of a sharpened tool to accelerate the work. From *S. officinarum* the stems, previously topped, and with the leaves manually removed to elaborate the silos, were utilized.

The silos consisted in plastic bags, with airtight closing and average weight of 15 kg of fresh forage.

The *S. officinarum* stems and *M. esculenta* leaves were separately chopped, with average particle size of 2,5 cm. For such purpose static choppers with electrical engine were used. The experimental mixtures of both components were made on fresh basis and they were done in 20-cm layers, compaction was performed with cement tampers. After removing the air completely, the bags were sealed with duct tape. The storage site was located in a dry and covered place. The silo opening was pre-fixed at 60 days (DAE), according to previous works conducted in the zone by Burgos *et al.* (2019),who determined the stabilization of silos of similar composition in that period of time.

Chemical and nutritional composition. The chemical and nutritional composition of the starting materials was determined at the beginning of the experiment. At the end, the composition of the mixtures was evaluated by taking aliquots from different strata, in order to make a composite sample. Dry matter (% DM) was determined by the weight difference of samples weighed in fresh, and after being dried in stoves at 65 ºC until reaching constant weight. The chemical composition was carried out from a nitric-perchloric digestion, where the following determinations were made: phosphorus (P, %) by colorimetric method (Chapman and Pratt, 1986); nitrogen (N, %) according to the methodology proposed by AOAC (2019); potassium (K, %) through flame photometry (Dewis and Freitas, 1970); calcium (Ca, %) and magnesium (Mg, %) by complexometrics. Crude protein (CP) was calculated by formula from the N content, multiplying it by the conversion factor 6,25 (Page *et al.*, 1982). The content of acid detergent fiber (ADF, %) was determined by the method suggested by Van Soest and Wine (1967). The parameters digestibility (DIG, %), total digestible nutrients (TDN, %) and digestible energy (DE, Mcal/kg DM) were calculated through the formulas proposed by Undersander *et al.* (1993), where:

$$DIG = 88{,}9 - (\%\ ADF \times 0{,}779)$$

$$TDN = 96{,}35 - (\%ADF \times 1{,}15)$$

$$DE = 0{,}04409 \times TDN$$

Fermentative quality of the silages. The fermentative quality of the silages was determined from pH (2,5:1 ratio in water), according to Dewis and Freitas (1970). The organoleptic evaluation was carried out according to the table of indicators proposed by Sanchez-Ledezma (2018), with modifications in the color scale, adapted to the mixtures of the processed materials.

Statistical analysis. With the obtained results the arithmetic means and standard errors were calculated. A variance analysis (ANOVA) of the studied variables was performed, with previous verification of the normality criteria according to the Shapiro-Wilks test. The means were compared through Tukey's multiple range test, for a significance level of $p < 0{,}05$. The statistical package used was InfoStat®, professional version 2020 (Di-Rienzo *et al.*, 2019).

Results and Discussion

Chemical composition of the forage material. Table 2 shows the results of the chemical and nutritional analysis of the materials that made up the silages.

Regarding the *M. esculenta* leaves, 21,8 % DM (table 2) was obtained, similar value to the one reported by Burgos *et al.* (2019) in different varieties. These authors determined that there can be certain variations in the DM percentage of the different fractions of the plant, being higher in the lower third. Some experts consider utilizable for animal feeding only the upper third of the foliage, because it is richer from the nutritional point of view (Martinez-Viloria, 2019). Nevertheless, it is feasible to utilize all the leaves of the plant at the moment of root harvest to prevent it from being wasted and make an integral use of it.

An outstanding characteristic of the *M. esculenta* leaves is their CP content, which in this trial was higher than 20 % (table 2), reason for which it was used to improve the nutritional quality of the *S. officinarum* silages. Another relevant characteristic is the concentration of minerals, such as P, K and Ca, which in this study was practically twice as much as that of the *S. officinarum* stems (table 2). The quality of *M. esculenta* leaves can vary according to the environment, cultivar and nutritional management of the lot where it is established. For such reason, it is important to know the characteristics of the material used for elaborating the silos (Burgos *et al.,* 2019).

S. officinarum can also show variations in its chemical composition, which depend on the interaction

Table 2. Chemical composition of *M. esculenta* leaves and *S. officinarum* stems used for elaborating the silos.

Variable	*M. esculenta* leaves	*S. officinarum* stems
DM, %	21,8	27,7
CP, %	21,7	2,9
ADF, %	31,9	26,4
DIG, %	61,7	68,5
P, %	0,3	0,1
K, %	1,1	0,6
Ca, %	2,7	1,4
Mg, %	0,3	0,3
TDN, %	64,6	62,1
DE, Mcal/kg DM	2,8	2,7

CP: Crude protein, ADF: acid detergent fiber, DIG: digestibility, TDN total digestible nutrients; DE: digestible energy

between regrowth age and the plant fraction that is analyzed. Particularly, the DM content responds to these indicators, but for the P and K content the dependence on the variety is also added (Fernández-Gálvez *et al*., 2018). Regarding the work conducted by Lagos-Burbano and Castro-Rincón (2019), the CP content of *S. officinarum* was low, and did not exceed 3 % DM; while the digestibility values did coincide with the ones reported by above-cited authors.

Evaluation of the silages. Regarding the organoleptic evaluation, all the silages showed a nice ripe fruit smell, as well as different shades of green color, according to the proportion of the original materials in the mixtures. The texture was well defined, with easy separation of the components in all the silos, for which they were considered silages of optimum quality. Although the organoleptic indicators constitute a subjective evaluation of the quality of silage through the senses, they have become the most utilized and practical evaluation alternative (Sanchez-Ledezma, 2018).

During the conservation process transformations occur that define the fermentation quality of the silo; and it is considered that pH is one of the most radical changes that occur (Sanchez-Ledezma, 2018). The pH of the ensiled mixtures up to the 50:50 proportion, did not show significant differences ($p < 0{,}01$), with an average of 3,6 for T1 and T2. Nevertheless, in T3, with 70 % of *M. esculenta* leaves, pH increased significantly, and reached a value of 3,7 (table 3). These changes can be related to the increases shown by shrubs like

Table 3. Chemical composition of the ensiled material at 60 days for the evaluated treatments.

Variable	Treatment *M. esculenta*: *S. officinarum*				P - value
	T1-30:70	T2-50:50	T3-70:30	SE ±	
DM, %	21,6	22,2	24,4	0,720	0,067
pH	3,6[a]	3,6[a]	3,7[b]	0,020	0,007
CP, %	8,4[a]	12,8[b]	16,0[c]	0,540	0,003
ADF, %	47,5[b]	45,3[b]	38,3[a]	0,920	0,024
DIG, %	51, 9[a]	53,6[a]	59,1[b]	0,710	0,024
TDN, %	47,8[a]	51,1[b]	57,7[c]	0,710	0,024
DE, Mcal/kg DM	2,1[a]	2,3[b]	2,5[c]	0,030	0,024
P, %	0,2[a]	0,2[b]	0,2[b]	0,010	0,010
K, %	1,0[a]	1,1[b]	1,1[b]	0,020	0,010
Ca, %	2,0	2,0	2,0	0,190	0,974
Mg, %	0,3	0,3	0,3	0,030	0,443

Different letters in rows: means that differ significantly for Tukey $p \leq 0{,}05$
CP: Crude protein, ADF: acid detergent fiber, DIG: digestibility, TDN total digestible nutrients; DE: digestible energy

M. esculenta, in the buffer capacity with regards to grasses (Alpízar *et al*., 2014). In spite of these differences, in all treatments pH was lower than 4, which indicates that the fermentation process was satisfactorily developed (Sanchez Ledezma, 2018).

The DM content of the silos was not different among treatments, and as average it was 22,7 %, lower value than the minimum of 25 % reported by Sanchez Ledezma (2018). The treatment with the highest proportion of *M. esculenta* leaves (T3) was the closest one to the recommended values, which ranks it as the most adequate of the three, with 24,43 % (table 3).

The CP of the silages showed significant differences ($p < 0,05$) in direct proportion with the increase of the *M. esculenta* leaf ratio in the silages. This allows to consider that the inclusion of the leaves from this plant in mixtures with *S. officinarum* is appropriate for the supplementation of ruminants, as complement of a balanced diet. The results of T1 coincide with previous studies, published by Burgos *et al*. (2019).

Regarding the protein content, it is estimated that the concentration lower than 7 % of this nutrient could generate deficiencies in the nitrogen metabolism in the rumen, because the value of this element in the diet is reduced, which compromises the adequate functioning of the rumen (Rojas-Cordero *et al*., 2020). From the evaluated treatments, none showed CP concentrations lower than 7 %. Treatment T3 stood out, which reached close values (16,3 %) to those of the energy-protein concentrate feeds, and much higher than the traditional silages of *Zea mays* L., sunflower (*Helianthus annuus* L.) and other grasses (Pereira *et al*., 2007; De-León and Giménez, 2019).

At 60 days of ensiling, the ADF content increased with regards to the original material (tables 2 and 3). In other works, conducted with silos of pure *S. officinarum*, and in silages of forage woody plants, increases were also found in the ADF content, after being ensiled (Aguirre *et al*., 2010; Roa and Galeano, 2015). In the silos, the inclusion of up to 50 % *M. esculenta* leaves (T1 and T2) did not produce significant changes in ADF (%). However, with 70 % of *M. esculenta* leaves (T3) significant decrease of the ADF content occurred and, subsequently, digestibility increased, which represents a benefit for animal feeding.

Regarding TDN, values between 47,8 and 57,7 % were recorded for T1 and T3, respectively. The TDN value of T3 was higher than the average of alfalfa silage, according to the report by Gallardo (2015). The DE reached values between 2,1 and 2,5 Mcal/kg DM for T1 and T3, respectively. The TDN and DE contents significantly increased, in direct proportion with the increase of the content of *M. esculenta* leaves in the ensiled mixture.

The ensiling process would increase the quantity of nutrients that are utilizable by the animal (López-Herrera *et al.,* 2017). Similar results were reported by Rojas-Cordero *et al*. (2020) in evaluations of silages with tropical species (*Musa* sp. and *Morus alba* L.).

The percentage of P in the silos stands out, which was 0,2 %; for which it was found over the average values cited by Mufarrege (1999) in the pasturelands of the eastern region of the Corrientes province, which do not exceed 0,1 % in DM.

Lagos-Burbano and Castro-Rincón (2019) emphasized the low digestibility of *S. officinarum*, and considered it forage of regular quality, for which they recommend its supply accompanied by a source of protein and minerals.

Considering the above-explained facts, the results of this study show the contribution of the *M. esculenta* leaves to the *S. officinarum* silages, for which they can be successfully ensiled to supplement nutritional deficiencies of animal husbandry of the Argentinean northeast. More specific studies even show that the high rates of weight gain, recorded when providing the *M. esculenta* foliage as only source of protein and fiber in the diet, indicate that it is very likely that part of the protein of *M. esculenta* foliage escapes from rumen fermentation and works, at least partially, as source of bypass protein (Preston *et al.,* 1999; Vera-Arteaga *et al*., 2019).

The *M. esculenta* foliage, besides having high nutritional value, is very well accepted by the animals, according to observations made in Argentina by Uset (2009). In correspondence with the report by Alpízar *et al.* (2014), the elaboration of mixed silages has the advantage of utilizing, simultaneously, the yields and fermentation potential of grasses, along with the higher protein levels shown by shrubs, which allows to obtain a higher-quality silage.

Conclusions

The incorporation of *M. esculenta* leaves in the *S. officinarum* silage increased its nutritional value, because it improved the protein contents and decreased the fibrous component. The inclusion of 70 % of *M. esculenta* leaves was the best treatment, because it also reached an adequate pH to preserve the material and dry matter content closer to the recommended one.

Acknowledgements

The authors thank the General Science Secretariat of the National University of the Northeast for the funding granted for the execution of this research through PI A18/001. Gratitude is also expressed to the students of the career of Agronomic Engineering of the UNNE, Ms. Deborah Alarcón and Mr. Emmanuel Valussi, for the collaboration given in the field and laboratory work, respectively.

Authors' contribution

Ángela María-Burgos. Conceived the research, organized the ideas for their materialization, established the design and setting up of the experiments, did the bibliographic search and manuscript writing.

Miriam Porta. Carried out the data taking and processing (chemical analyses). Besides, searched for bibliography and participated in the manuscript writing and revision.

Claudina María-Hack. Carried out the data taking and processing (chemical analyses). Besides, searched for bibliography and participated in the manuscript writing and revision.

María Elena Castelán. Participated in the supervision of the research, as well as in the manuscript revision and bibliographic search.

Conflict of interests

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

Bibliographic references

Aguirre, J.; Magaña, R.; Martínez, S.; Gómez, A.; Ramírez, J. C.; Barajas, R. *et al.* Caracterización nutricional y uso de la caña de azúcar y residuos transformados en dietas para ovinos. *Zootecnia Trop.* 28 (4):489-498. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0798-72692010000400005&lng=es&tlng=es, 2010.

Alpízar, A.; Camacho, M. I.; Sáenz, C.; Campos, M. E.; Arece, J. & Esperance, M. Efecto de la inclusión de diferentes niveles de morera (*Morus alba*) en la calidad nutricional de ensilajes de sorgo (*Sorghum almum*). *Pastos y Forrajes*. 37 (1):55-60. https://www.redalyc.org/pdf/2691/269131241007.pdf, 2014.

AOAC. *Official methods of analysis*. Rockville, USA: AOAC International, 2019.

Burgos, Ángela M. Estado actual del cultivo de mandioca en la República Argentina. *Agrotecnia (Chaco, Argentina)*. 27:14-18, 2018. DOI: http://dx.doi.org/10.30972/agr.0273482.

Burgos, Ángela M.; Porta, Miriam; Hack, Claudina M. & Castelan, María E. Aptitud forrajera de hojas de yuca (*Manihot esculenta* Crantz) y su aporte a la calidad nutricional de microsilos de caña de azúcar. *Rev. Vet., Argentina*. 30 (2):73-81. http://vet.unne.edu.ar/, 2019.

Cardona-Iglesias, J. L.; Mahecha-Ledesma, Liliana & Angulo-Arizala, J. Efecto sobre la fermentación *in vitro* de mezclas de *Tithonia diversifolia*, *Cenchrus clandestinum* y grasas poliinsaturadas. *Agron. Mesoam*. 28 (2):405-426, 2017. DOI: https://dx.doi.org/10.15517/ma.v28i2.25697.

Chapman, H. D. & Pratt, P. F. *Métodos de análisis para suelos, plantas y aguas*. México: Editorial Trillas, 1986.

De León, M. & Giménez, R.A. Ensilajes de sorgo y maíz: rendimiento, composición, valor nutritivo y respuesta animal. Ensilajes de sorgo y maíz: rendimiento, composición, valor nutritivo y respuesta animal. https://www.engormix.com/ganaderia-carne/articulos/ensilajes-sorgo-maiz-rendimiento-t43931.htm?utm_source=campaign&utm_medium=email&utm_campaign=1-1-0&src_ga=2, 2019.

Dewis, J. & Freitas, F. *Métodos físicos y químicos de análisis de suelos y aguas*. Roma: FAO. Boletín No. 10, 1970.

Di Rienzo, J. A.; Casanoves, F.; Balzarini, Mónica G.; Gonzalez, Laura; Tablada, Margot & Robledo, C. W. *InfoStat versión 2019.* Córdoba, Argentina: Centro de Transferencia InfoStat, FCA, Universidad Nacional de Córdoba. http://www.infostat.com.ar, 2019.

Elizondo-Salazar, J. A. Producción de biomasa y calidad nutricional de tres forrajes cosechados a dos alturas. *Agron. Mesoam*. 28 (2):329-340, 2017. DOI: https://doi.org/10.15517/ma.v28i2.23418.

Escobar, E. H.; Ligier, D.; Melgar, M.; Matteio, H. & Vallejos, O. *Mapa de suelos de los Departamentos de Capital, San Cosme e Itatí de la provincia de Corrientes, Argentina*. Argentina: INTA, ICA, CFI, 1994.

Fernández-Gálvez, Y.; Pedraza-Olivera, R. M.; Llanes-Díaz, Ailsa; Hermida-Baños, Y.; Torres-Varela, Isabel C.; Montalván-Delgado, J. *et al.* Indicadores de la composición química en caña de azúcar según edad de rebrote, cultivar y fracción de la planta. *Rev. prod. anim*. 30 (1):1-7. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2224-79202018000100001&lng=es&tlng=es, 2018.

Gallardo, M. *Forrajes conservados. Aspectos nutricionales y diagnóstico de calidad.* https://www.forratec.com.ar/uploads/54-20150204190745-pdfEs.pdf, 2015.

Gil-Llanos, J. *Uso de yuca en la alimentación animal.* Cali, Colombia: Corporación Clayuca. http://ciat-library.ciat.cgiar.org/Articulos_CIAT/Digital/67460_Uso_de_la_yuca_en_alimentaci%C3%B3n_animal.pdf, 2015.

Lagos-Burbano, Elizabeth & Castro-Rincón, E. Caña de azúcar y subproductos de la agroindustria azucarera en la alimentación de rumiantes. *Agron.*

Mesoam. 30 (3):917-934. 2019. DOI: https://dx.doi.org/10.15517/am.v30i3.34668.

López-Herrera, M. & Briceño-Arguedas, E. Efecto de la especie de leguminosa y la fuente de carbohidratos en la calidad física y química de mezclas para ensilaje. *Nutr. Anim. Trop*. 11 (1):52-73, 2017. DOI: http://dx.doi.org/10.15517/nat.v11i1.29605.

López-Herrera, M.; Rojas-Bourrillon, A. & Zumbado-Ramírez, C. Características nutricionales y fermentativas de ensilados de pasto Camerún con plátano Pelipita. *Agron. Mesoam*. 28 (3):629-642, 2017. DOI: https://doi.org/10.15517/ma.v28i3.25237.

Martinez-Viloria, F. *Yuca forrajera para la alimentación bovina*. Argentina: Ministerio de Producción de Corrientes. https://infopastosyforrajes.com/suplementacion/yuca-forrajera-para-la-alimentacion-bovina/, 2019.

Ministerio de Producción. Sector ganadero. Corrientes, Argentina: Ministerio de Producción de Corrientes. http://www.mptt.gov.ar, 2019.

Mufarrege, D. J. *Los minerales en la alimentación de vacunos para carne en la Argentina*. Corrientes, Argentina: Public. Divulg. Técn., INTA Mercedes. https://www.produccion-animal.com.ar/suplementacion_mineral/60-minerales_en_la_alimentacion_vacunos.pdf, 1999.

Murphy, G. M., Ed. *Atlas Agroclimático de la Argentina*. Buenos Aires: Facultad de Agronomía, Universidad de Buenos Aires, 2008.

Page, A. L.; Miller, R. H. & Keeney, Y. *Methods of soil analysis, chemical and microbiological propertiers*. Madison, USA: Soil Sci. Soc. Am. Cap. 2, 1982.

Pereira, L. G.; Gonçalves, L. C.; Rodriguez, N. M. & Tomich, T. R. Ensilaje de girasol como opción forrajera. *Jornada sobre Producción y Utilización de Ensilajes*. Brasil: EMBRAPA. http://www.cpatsa.embrapa.br/public_eletronica/downloads/OPB1719.pdf, 2007.

Porta, Miriam; Burgos, Ángela M.; Castelán, María E. & Hack, Claudina M. Uso forrajero del follaje de mandioca: un cambio de paradigma productivo para un cultivo tradicional del NEA. *Agrotecnia*. 29:50-54, 2020. DOI: http://dx.doi.org/10.30972/agr.0294520.

Preston, T. R.; Rodríguez, L.; Nguyen, V. L. & Le, H. C. *El follaje de la yuca (*Manihot esculenta *Crantz) como fuente de proteína para la producción animal en sistemas agroforestales*. Conferencia electrónica "Agroforestería para la producción animal en Latinoamérica". Roma: FAO. 1999.

Ramírez-de-la-Ribera, J. L.; Zambrano-Burgos, D. A.; Campuzano, Janeth; Verdecia-Acosta, D. M.; Chacón-Marcheco, E.; Arceo-Benítez, Y. *et al.* El clima y su influencia en la producción de los pastos. *REDVET*. 18 (6):1-12. http://www.redalyc.org/articulo.oa?id=63651420007, 2017.

Roa, María L. & Galeano, J. R. Calidad nutricional y digestibilidad *in situ* de ensilajes de cuatro leñosas forrajeras. *Pastos y Forrajes*. 38 (4):431-440. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942015000400007, 2015.

Rojas-Cordero, D.; Alpízar-Naranjo, A.; Castillo-Umaña, M. Á. & López-Herrera, M. Efecto de la inclusión de *Musa* sp. en la conservación de *Morus alba* Linn. *Pastos y Forrajes*. 43 (3):210-219. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942020000300210, 2020.

Sanchez-Ledezma, W. Potencial de los forrajes para producir ensilages de calidad. *Revista Alcances Tecnológicos*. 12 (1):49-58, 2018. DOI: https://doi.org/10.35486/at.v12i1.37.

Tagliapietra, Bruna L.; Silva, Maritiele N. da; Freitas, C. P. de O. de; Richards, Neila S. P. dos S. & Zanon Jr., A. Teores de proteína em silagem de yuca elaboradas a partir de cultivares de mesa e forragem. *Agroecossistemas*. 11 (2):181-194, 2019. DOI: http://dx.doi.org/10.18542/ragros.v11i2.7299.

Undersander, D.; Combs, D. & Shaver, J. R. Milk per acre spreadsheet for combining yield and quality into a single term. *J. Prod. Ag*. 6:231-235. https://fyi.extension.wisc.edu/forage/files/2016/11/Milk-2016-Combining-Yield-and-Quality-into-a-Single-Term-2.pdf, 1993.

Uset, O. A. Utilización de raíces y parte aérea de mandioca en la alimentación animal. *Informe Técnico EEA-INTA Montecarlo*. 62. Misiones, Argentina. p. 15-17, 2009.

Van Soest, P. J. & Wine, R. H. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. *J. Assn. Offic. Anal. Chem*. 50:50-55, 1967. DOI: https://doi.org/10.1093/jaoac/50.1.50.

Vera-Arteaga, T. A.; Zambrano-Vélez, María I. & Muñoz-Murillo, J. P. Raciones suplementarias con follaje de yuca (*Manihot esculenta* Crantz) en la alimentación de vacas lecheras Brown Swiss. *ProSciences*. 3 (19):10-15, 2019. DOI: https://doi.org/10.29018/issn.2588-1000vol3iss19.2019pp10-15.