Bromatological and morphological characterization and yield of sugar cane top in Huasteca Potosina, Mexico

H. Ramírez-Cathí[1], Aida C. C. Salcedo[1], F. Briones[2], F. A. Lucero[2], Alicia Cárdenas[2], C. Marcof[3] and J. C. Martínez[2]

[1]*Instituto Tecnológico de Ciudad Valles, Ciudad Valles, San Luis Potosí, México*

[2]*Universidad Autónoma de Tamaulipas-Facultad de Ingeniería y Ciencias, Ciudad Victoria, Tamaulipas, México*

[3]*Universidad Autónoma Chapingo-Departamento de Zootecnia, Texcoco, México*

Correo electrónico: jmartinez@uat.edu.mx

Morphological and bromatological composition was determined in four sugar cane varieties, burnt and green harvested. Three bunch were obtained per farms, belonging to 679 partners of the sugar mill "Plan de Ayala". Bunch were weighed and quantified, separating stems from tops. The morphological evaluation was performed according to bunch weight, stem, sugar cane top, dry straw, green leaves, remaining top or apex. For the bromatological characterization, sugar cane tops were cut (5 mm cuts) and dried until reaching a constant weight between 90 and 95% of dry matter. The bromatological analysis determined dry matter, crude protein, ash, neutral detergent fiber, acid detergent fiber and *in situ* degradability. Variables were analyzed through a 4x2 factorial (four varieties and two harvests) in a completely random design. Varieties used were 02-CP72-2086, 03CO-997, 202MEX55-32 and 24MEX68-1366, and the harvests were green and burnt. Bunch production was different (P< 0.05). However, canes per bunch, stem percentage, tops and straws were not modified by variables. Likewise, factor harvest only affected (P<0.05) kilograms/bunch^{-1} and dry straw. General means of dry matter, crude protein, ash, neutral detergent fiber and acid detergent fiber were 93.1, 3.0, 5.9, 58.2 and 33.6%, respectively, without significant effect, due to the variety. General means for green and burnt sugar cane tops were similar to those of varieties with significant effect (P > 0.05), due to the harvesting method. It can be concluded that sugar cane top can be used as an input of ruminal feeding.

Key words: *nutritional quality, Saccharum officinarum, tropic*

In Mexico, like in many tropical countries, growing sugar cane (*Saccharum officinarum*) has great biomass yields, for being one of the most efficient vegetables in solar energy use. Nowadays, by-products that are not used by sugar industry can be used as inputs for animal feeding, mainly during times of crisis. This can be translated into savings for animal breeders.

In Mexico, during the sugar cane harvest of 2012, an amount of 703.761 ha of sugar cane was planted and a harvest of more than 46 millions of tons of milled sugar cane was achieved (SIAP 2013). Likewise, in the state of San Luis Potosí, around 68.787 ha of sugar cane were planted, which produced 3,556.110 t, with yields of 58.95 t ha^{-1} (SIAP 2013).

Sugar cane is characterized by its good ability of adapting to soils, climate, management, topography, fertility and agronomic management, its great capacity of green and dry matter production per unit of area, its availability in periods of low presence of traditional forages (pastures). Besides, it has an aggregate value because it uses biomass not use in the industry (tops, leaves, sprouts, and immature stems).

Sugar cane produces great amount of biomass, which is composed, in its maturity state, by 71.8% of stems, 12.6% of tops, 8.7% of leaves and 6.9% of sprouts (Torres 2006). However, its protein levels are under the requirements of ruminants (Araque *et al.* 2003), and its contents of total sugars and fiber are high. Pozo (2011) analyzed the bromatological characteristics of sugar cane at different ages and reported the percentages of dry matter (DM), crude protein (CP), ash (A), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were 19.3, 4.3, 7.4, 61.2 and 38.2%, respectively.

Sugar cane, in feeding systems, is considered as an excellent alternative for food saving. Besides, it is able to produce more amount of DM, soluble carbohydrates and forage biomass than any other tropical gramineous. This potential made the sugar cane the most significant forage of all existing grasses in tropical areas and it can withstand a high stocking rate (Pozo 2011). However, sugar cane top could be an important feeding source, only if it is taken into account its limitations as only source of nutrients for ruminant diets (Galina *et al.* 2007).

The objectives of this study were to determine yield and bromatological and nutritional characteristics of sugar cane top of four varieties and divided into two harvest methods: green and burnt. They were used for feeding ruminants.

Materials and Methods

The experiment was developed in the area of the sugar mill "Plan de Ayala" (IAPA), located in Ciudad Valles, San Luis Potosí, México. This region is located at 22° 00' 14" N, 99° 01'42" W, at 80 m o.s.l. The climate is Aw, according to Köppen classification, modified by García (1987), which correspond to a humid warm weather, with rains during summer. Annual average precipitations are 1,112 mm and the rainy season goes from May to October. Annual average temperature is

25.5º C.

A survey was carried out with 679 sugar cane producers from the area of IAPA. With the information recorded, production cycle, sown surface per variety, sugar canes per thirds and kilograms of sugar cane (stems). The varieties to study were determined using this data.

Sampling of sugar cane varieties started during the early (February), intermediate (March) and late (April) harvest. In order to demonstrate the benefit of not using fire during the harvest, two samplings of sugar cane top were used: green and burnt. Three samples per farm were taken systematically, according to the methodology of Molina *et al.* (1995).

Three bunch of high, intermediate and regular quality were collected per variety and per harvest condition: green and burnt. Bunch were cut at soil level and an average of 3 cm of stem over the stem butts, as sugar cane cutters used to do. Each bunch was wrapped in clean flour bags, along with a label with data (producer name, location, variety, condition and quality)

Samples were moved to the Laboratorio de Alimentos Balanceados de Agronomía, belonging to the Instituto Tecnológico de Ciudad Valles (ITV). For the morphological characterization of sugar cane, bunch were weighed and quantified (stems separate from tips). Later, sugar cane top was fractioned and the different components (green leaves, dry leaves, pods (apex) or sugar cane top) were weighed.

Sugar cane tops were ground with a cane chopper HML Xalapa M-200®. Samples were kept in flour bags, previously labeled. Later, they were dried at room temperature over a concrete floor. Afterwards, aliquots were located into gray paper bags, with small holes for accelerating the dehydration process and avoiding any fermentation process that would affect the chemical composition. An amount of 72 sub-samples, equivalent to 12 plots of producers were obtained. From those sub-samples, an amount of 24 mixed samples were formed.

For proximal analysis, the official methods of food analysis (van Soest *et al.* 1991 and Horwitz and Latimer 2005) were used for the components of ADF and NDF. The analyses were performed at Laboratorio de Nutrición Animal del Colegio de Posgraduados in Montecillo, Mexico.

The analyses of *in situ* digestibility (DIG) (Ørskov and McDonald 1979) were performed at the facilities of ITV. For that purpose, three Pelibuey lambs, with cannula in the rumen, were used. The lambs were kept in individual metabolic cages and were fed *ad libitum*. Three experimental periods were used, with ten days of adaptation before the incubation of bags into the rumen. For ruminal incubation of samples, nylon bags of 5 x 10 cm and 53 μm were used. These bags were incubated by duplicate for 48 h. Degradation of DM at time zero was estimated with the equation of Ørskov and McDonald (1979).

The analysis of variance was applied to data, according to a completely random design, with a factorial arrangement of 4x2 (SAS 2001). The four varieties were factor A and the conditions of harvest (green or burnt) were factor B, with three repetitions per treatment.

Variables bunch weight, stem, sugar cane top, dry straw, green leaves, remaining sugar cane top or apex were analyzed for the morphological evaluation. For the chemical composition, the variables were: DM, A, CP, NDF, ADF and *in situ* DIG. The means comparison test of Duncan (1955) was applied in the cases of significant effect. In preliminary analysis, the effect of the interaction of varieties per type of harvest was studies but it was not significant.

Results and Discussion

Out of the analyzed information, three groups of varieties were found: late, intermediate and early cycles. From data processed, the average yield estimated was 34.4 t of sugar cane ha^{-1}. The variety 03CO-997 was highlighted with the best yields of the intermediate and late harvest, with 40.8 and 38.2 t of sugar cane ha^{-1}.

From the information provided by producers, it was determined that the most predominant varieties in production from the area of IPA were: 02-CP72-2086, 03CO-997, 24MEX68-1366 and 202MEX55-32 (table 1).

The estimated yields can be considered as low (33.4 t ha^{-1}) because, according to Servicio de Información Agroalimentaria y Pesquera, national yields of sugar cane were 65.5 and 65.7 t ha^{-1}, for harvests of 2011 and 2012 respectively (SIAP 2013). Despite of this situation, Mexico participated with 3% of sugar in the world market. García and Spreen (2000) found out that national average was 71.5 t ha^{-1}, between 1989 and 1993. Díaz *et al.* (2012) found that sugar cane production in Venezuela was higher than the one referred in this study.

The resulting information indicates the great amount of forage or sugar cane top (by-product), available as food source for big and small ruminants. However, several factors influence on sugar cane production and, consequently, yields can range constantly, depending on the agronomical management of crops, soil fertility, variety, and some others.

Table 2 shows the results of the morphological evaluation according to canes per bunch, bunch, stems and tops. Regarding the canes per bunch, there were no significant differences because varieties. These results do not coincide with those informed by López *et al.* (2003), who confirmed the effect ($P<0.05$) of the different varieties cultivated in the state of Tabasco, Mexico. However, regarding kilograms per bunch, the variety 03CO-997 had the best performance with 10.2±3.3 kg. This variety was different ($P<0.05$) from 202MEX55-32 and 02-CP72-2086, but statistically equal to variety 24MEX68-1366.

Percentages of stems and tops were not modified due

Table 1. Varieties, amount of producers, sown surface, estimate production and yields per hectares of sugar cane in the area of the sugar mill "Plan de Ayala"

Third of harvest	Varieties	Producers	ha	t	Production (t ha^{-1})
Second	02-CP72-2086	51	134.0	4589.0	34.2
Second	03CO-997	224	910.3	37158.0	40.8
Second	202MEX55-32	186	586.5	15940.0	27.2
Second	24MEX68-1366	14	46.0	1276.0	27.7
Third	02-CP72-2086	43	195.8	5312.0	27.1
Third	03CO-997	86	428.3	16375.0	38.2
Third	202MEX55-32	70	315.8	11588.0	36.7
Third	24MEX68-1366	5	29.0	1035.0	35.7

Tabla 2. Morphological composition (stem and top) of four varieties of sugar cane, evaluated in the area of the sugar mill "Plan de Ayala", in Ciudad Valles, San Luis Potosí, Mexico.

Indicator	24MEX68-136	03CO-997	202MEX55-32	02CP-72	Pr>F	R2	CV
Canes bunch^{-1}	10.83±0.84^{a}	10.21±0.78^{a}	10.71±0.63^{a}	11.17±1.84^{a}	0.55	0.32	12.34
Bunch, kg	8.96±2.26^{ab}	10.22±3.27^{a}	6.94±1.72^{b}	7.59±0.88^{b}	0.05	0.19	24.58
Stems, %	80.53±6.65^{a}	75.50±6.76^{a}	81.15±5.45^{a}	78.18±3.27^{a}	0.10	0.27	24.61
Aerial top, %	19.47±6.65^{a}	24.50±6.76^{a}	18.89±5.45^{a}	21.82±3.27^{a}	0.01	0.60	23.88
Top, %	10.74±2.93^{a}	10.32±1.87^{a}	11.04±2.66^{a}	9.75±1.68^{a}	0.78	0.24	12.06
Green leaves, %	4.41±2.30^{b}	7.15±2.26^{a}	4.53±1.36^{b}	5.31±1.41^{ab}	0.05	0.41	19.12
Dry straw, %	4.32±4.84^{a}	7.04±3.59^{a}	3.29±3.14^{a}	6.76±3.25^{a}	0.09	0.28	48.82

^{a,b} are different (P< 0.05), according to Duncan (1955)

to the effect of varieties (P > 0.05). These results do not coincide with those reported by López *et al.* (2003), who confirmed differences (P<0.05) among percentages of stems, tops and straws.

Stems had percentages between 75.5 and 81.2% of the sugar cane, while tops range from 18.9 to 24.5%.

Table 3 shows the results of the morphological evaluation according to type of harvest. There were only significant differences in canes per bunch, green leaves and dry straw (P < 0.05).

Table 4 shows the means of DM, CP, NDF, ADF, A and DIG. It was confirmed that varieties did not affect significantly (P > 0.05) the content of nutrients. The general mean of DM was 93.1%, which may be considered as high. Forage was previously dried to avoid fermentation problems. Similar results was reported by Vasallo (2007), who stated that sugar cane, cut in small pieces and dried under the sun, showed 94.8 % of DM content. However, Pozo (2011) referred that DM of sugar cane was modified by the age of the plant. Other authors (Aranda *et al.* 2009, Barcenas *et al.* 2009 and Leão *et al.* 2011) pointed out that DM of sugar cane was between 25 and 32.5 %. Aguirre *et al.* (2010) reported that quality of sugar cane forage was modified by the type of treatment used.

Regarding protein percentage, it was confirmed that varieties did not affect (P > 0.05) the content, which was an average of 3.3% (table 4). Similar results were reported by Pozo (2011) in 18-month-old sugar canes. Nevertheless, Vasallo (2007) and Leão *et al.* (2011) found percentages lower than 2.0 and 2.9 %, respectively.

Table 4 shows that the content of NDF in the four varieties of sugar cane was high. This allowed to keep its condition of "forage". Studies of several authors (Vasallo

Table 3. Morphological composition of sugar cane (stem and top), under two harvesting conditions, in the area of the sugar mill "Plan de Ayala", in Ciudad Valles, San Luis Potosí, Mexico.

Indicator	Burnt	Green	Pr>F	R2	CV
Cane bunch^{-1}	11.25±1.39^{a}	10.21±0.90^{b}	0.04	0.32	12.34
Bunch, kg	8.03±1.32^{a}	8.83±2.74^{a}	0.35	0.19	24.58
Stems, %	77.75±6.09^{a}	79.93±4.97^{a}	0.51	0.27	24.61
Aerial top, %	22.25±6.09^{a}	20.07±4.97^{a}	0.01	0.58	34.92
Top, %	11.30±2.45^{a}	9.63±2.13^{a}	0.51	0.48	40.30
Green leaves, %	5.97±2.18^{a}	4.73±1.48^{b}	0.01	0.59	34.92
Dry straw, %	4.99±3.47^{a}	5.72±3.93^{b}	0.01	0.61	87.86

^{a,b} Means within the line with different letter are different (P<0.05), according to Duncan (1955).

Table 4. Bromatological composition of sugar cane top of four varieties in the area of the sugar mill "Plan de Ayala" in Ciudad Valles, San Luis Potosí, Mexico

Content	Varieties				Pr>F	R^2	CV
	24MEX68-136	03CO-997	202MEX55-32	02CP-72			
DM, %	93.25± 0.24	92.63±0.63	93.16±0.35	93.20±0.20	0.55	0.32	12.3
CP, %	3.23±0.45	3.24±0.55	3.30±0.46	3.27±0.57	0.35	0.19	17.5
NDF, %	63.45±2.86	62.43±3.96	60.33±5.72	63.85±6.01	0.15	0.27	24.6
ADF, %	35.52±2.68	35.88±2.04	34.33±3.42	38.64±4.99	0.10	0.23	23.9
Ash, %	5.52±0.63	6.01±0.61	6.89±1.74	6.94±2.31	0.25	0.28	15.9
In situ DIG, %	59.23±5.07	60.36±3.40	61.28±3.41	58.95±3.95	0.20	0.30	24.6

Table 5. Chemical composition of sugar cane top under two harvesting conditions, in the area of the sugar mill "Plan de Ayala" in Ciudad Valles, San Luis Potosí, Mexico

Content	Harvest condition		Pr>F	R^2	CV
	Burnt	Green			
DM, %	93.08±0.45	93.03±0.26	0.55	0.32	29.3
CP, %	3.09±0.56	3.44±0.46	0.22	0.42	17.5
NDF, %	60.64±5.89	64.38±3.39	0.15	0.27	24.6
ADF, %	35.45±3.73	36.74±2.84	0.20	0.23	23.9
Ash, %	6.18±1.72	6.50±0.92	0.17	0.28	15.9
In situ DIG, %	60.64±4.72	59.27±3.20	0.20	0.30	24.6

2007, Aranda *et al.* 2009, Barcenas *et al.* 2009, Aguirre *et al.* 2010, Leão *et al.* 2011and Pozo 2011) referred values between 35.9 and 65.7 % for NDF.

Regarding the DIG of sugar cane top, the mean was 60.0%, without significant effects due to variety (table 4). Similar results were referred by Barcenas *et al.* (2009), who found that sugar cane top showed a DIG of 59.5%. Molina *et al.* (1999) stated that sugar cane for animal use must have, at least, 50 % of DIG of DM. Aguirre *et al.* (2010) analyzed *in vitro* DIG of the entire sugar cane and of ground residues and reported 68.3 and 75.3 %, respectively. These levels are superior to those referred in the literature (López *et al.*2003).

Means of DM, CP, NDF, ADF, A and DIG for sugar cane, according to the type of harvest (green or burnt), were 93.1, 3.3, 62.5, 36.1, 6.3 and 60.0 %, respectively (table 5). As for the varieties, none of the variables of response was affected due to the type of harvest.

DM content was the same for both harvests, with 93.1 %. This may have been caused by the previous dehydration of both forages. Pozo (2011) studied the sugar cane age and found significant differences ($P<0.05$) in the DM content. The 18-month-old crop showed a content of 25.1% of DM, while the crop of 24 months old showed a DM of 10.7%.

Contrary to the expectations, nutrient contents were similar in both types of harvest. However, CP contents were always under the requirements for the proper functioning of the rumen. Nutrient contents were very similar to those informed in the consulted literature (Vasallo 2007, Aranda *et al.* 2009, Barcenas *et al.* 2009, Pozo 2011y Leão *et al.* 2011).

Although there was no systematic evaluation of the biomass harvest, when fire was used to burn the biomass that was not used in the sugar mill, yield is confirmed to be higher when crops are not burnt. Therefore, a higher proportion of straw can be harvested when it is not burnt.

Varieties and type of harvest (green or burnt) did not affect the percentage of nutrients within sugar cane.

Sugar cane top is a good source of forage due to its content of NDF. However, for improving the use of the sugar cane top, it is recommended to harvest the tops before the burning process, in order to have higher volumes of biomass. Sugar cane top has low content of CP, so, it is recommended to supplement with true protein or non protein nitrogen compounds.

References

Aguirre, J., Magaña, R., Martínez, S., Gómez, A., Ramírez, J.C., Barajas, R., Plascencia, A., Barcena, R. & García, D.E. 2010. Caracterización nutricional y uso de la caña de azúcar y residuos transformados en dietas para ovinos. Zootec.Trop. 28:489

Aranda, E.M., Mendoza, G.D., Ramos, J.A., Salgado, S. & Vitti, A.C. 2009. Selectividad de caña de azúcar en bovinos. Rev. AIA 13:21

Araque, C., Espinoza, F., Fuenmayor, A., Simoes, D. & Sandoval, E. 2003. Efecto de la suplementación con caña de azúcar-urea en la ganancia de peso en mautas a pastoreo.

Rev Científica (LUZ) XIII: 352

Barcenas, G.R., Hernández, P.A., Meneses, M., Ramírez, E., Crosby, M.M. & Lee, A. 2009. Guía Práctica. Composición nutrimental y valor nutritivo de los forrajes del Estado de Puebla. Primera Edición. Fundación PRODUCE. Puebla, A.C. México. p. 29

Díaz, A., De Sousa, O., Briceño, R., Rea, R., George, J., Figueredo, L., Pérez, A., Niño, M., Aza, G. & Rivero, A. 2012. Descripción morfológica y valoración de la capacidad productiva del cultivar promisorio de caña de azúcar CR87-339 en Venezuela. INIA Divulga 21:5

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics. 11.1

Galina, M.A., Guerrero, M. & Puga, C.D. 2007. Fattening Pelibuey lambs with sugarcane tops and corn complemented with or without slow intake urea supplement. Small Ruminant Res. 70:101

García, E. 1987. Modificaciones al Sistema de Clasificación Climática de Köppen. Instituto de Geografía. UNAM. México. p. 246

García, C.L.R. & Spreen, T.H. 2000. La agroindustria Azucarera de México: Reformas estructurales y sus implicaciones para el mercado de edulcorantes. CIESTAAM. Universidad Autónoma de Chapingo. Reporte de Investigación 55. p. 44

Horwitz, W. & Latimer G.W. 2005. Official Methods of Analysis of AOAC International. 18th Ed. AOAC International. North Frederick Avenue Gaithersburg. Maryland, USA

Leão, A.G., García, A.S.S., Bezerra, G.M.M., Alves, H.B.S., Leal, H.P. & Battiston,C.M.L. 2011. Características nutricionais da carne de cordeiros terminados com dietas contendo cana-de-açúcarousilagem de milho e doisníveis de concentrado. Rev.Bras. Zoot. 40:1072

López, I., Aranda, E. M., Ramos, J.A. & Mendoza, G.D. 2003. Nutritional evaluation of eight sugarcane varieties with forage potential. Cuban J. Agric. Sci. 37:375

Molina, A.S., Leal, P.P., Tuero, O. & Blanco, C. 1995. Nota técnica acerca del método de muestreo para características morfológicas del valor forrajero de la caña de azúcar. Universidad Autónoma Chapingo. México

Molina, A., Leal, P.P., Vera, A., Milanés, N., Pedroso, D., Torres, V., Traba, J. & Tuero, O. 1999. Industrial varieties of sugar cane used as forage. *In situ* digestibility. Cuban J. Agric. Sci. 33:369

Ørskov, E.R. & McDonald, I. 1979. The estimation of protein degradability in the rumen form incubation measurements weighted according to rate of passage. J. Agric. Sci. 92:499

Pozo, C.B.D. 2011. Efecto del suministro de caña de azúcar (*Saccharum officinarum*) cosechada en tres diferentes edades en el levante de novillas. Degree Thesis. Escuela Politécnica del Ejército, Departamento de Ciencias de la Vida. Sangolquí, Ecuador. p. 139

SAS. 2001. User‘s Guide Statistics. Institute Inc. Cary, NC, USA

SIAP. 2013. Caña de azúcar. Servicio de Información Agroalimentaria y Pesquera-Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Available on: http://www.siap.gob.mx/index.php?option=com_wrapper&view=wrapper&Itemid=351. [Consulted: January 31st, 2013]

Torres, M. J. A. 2006. Uso de la caña de azúcar como parte de la ración para engorde de ganado. Congreso de la Asociación de Técnicos Azucareros de Centroamérica. San José, Costa Rica. 2: 865

Van Soest, P.J., Robertson, J.B. & Lewis, B.A. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583

Vasallo, M. 2007. Caña de azúcar, mandioca y batata para forraje en la producción intensiva de carne. Centro de Investigaciones Nematológicas, Corrientes, Argentina. Available on: http://www.produccion-animal.com.ar/informacion_tecnica/.pdf. [Consulted: January 31st, 2013]

Received: June 6, 2013