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Analysis of the industrial quality of three sugarcane cultivars at "Santa Rosalía de la Chontalpa" sugarcane mill

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ABSTRACT

Objective: To evaluate the industrial quality of three sugarcane cultivars during the plant cycle at the supply area of "Santa Rosalía de la Chontalpa" sugarcane mill.

Design/Methodology/Approach: An experiment was established under a factorial design 3×3 (3 cultivars: CP 72-2086, MEX 79-431 and MEX 69-290; × 3 sampling dates: 330, 390 and 450 days after sowing (DAS)) on an Eutric Fluvisol soil. In each plantation, a sample of 10 stems with three replications was collected to determine the industrial quality by polarimetry.

Results: The industrial quality of the evaluated cultivars only differed statistically in terms of the percentage of purity, MEX 79-431 was the one that presented the lowest value for this variable. At 450 DAS, the highest value was observed for °Brix (17.28), POL percentage (14.92), purity (86.44%). The values obtained in the present study for the quality of juice in the evaluated cultivars are within the range of the standard values established for Mexico.

Limitations/Implications: Polarimetry is still the method used by most of the sugar mills in Mexico, even if other more environmental-friendly methodologies exist.

Findings/Conclusions: The trend line that best fit to MEX 69-290 and MEX 79-431, for °Brix, POL and purity, was a linear polynomial and to CP 72-2086, a polynomial quadratic. Fresh stems humidity and reducing sugars showed best fit with an inverse polynomial. °Brix presented strong and positive correlation with POL (R=0.99**); and strong and negative with reducer sugars (R=−0.95**) and fresh stem humidity (R=−0.91**).

Keywords: industrial quality, sugar cane, cultivars.

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INTRODUCCIÓN

The economic success of sugarcane cultivation is determined by the accumulation of sucrose in the internodes of their milling stems (Batta *et al*., 2002), the maturation process being fundamental for the industry, since it needs to alternate the farms and harvest periods to have a control that guarantees the supply of good quality raw material throughout the harvest (Moura *et al*., 2014). For this, it is necessary to have cultivars of early, medium and late maturing.

The sugarcane payment system currently adopted by the vast majority of sugar and alcohol industries is that of total recoverable sugars, called TRS. In this system, the quality of the sugarcane juice delivered to the mills and distilleries is evaluated by the content of soluble solids, apparent sucrose, reducing sugars and fibers. Therefore, cultivars that have a better quality of raw material and allow a higher industrial yield for the production of sugar and alcohol are of great importance for a rational exploitation of sugarcane (Da Silva *et al*., 2013). The ripening process of sugarcane is closely related to the age and cycle of the crop, and to the climatic conditions, but the genetic character is decisive. In terms of genetic materials, in Mexico, sugarcane production is mainly based on three genotypes: CP 72-2086, MEX 79-431 and MEX 69-290, which together occupy 74% of the designated area. to this crop in the country (Sentíes-Herrera and Gómez-Merino, 2014).

The reference values of the quality parameters of sugarcane juice in Mexico are: sucrose and POL of 12.5%, Brix degrees (°Brix) of 18 - 22, purity of 79 to 89%, fiber of 11 to 15%, humidity of 73 - 75% and reducing sugars close to zero (Salgado *et al*., 2003). For all the above, the objective of this work was to evaluate the industrial quality of three sugarcane cultivars during the plant cycle, in the supply area of Santa Rosalía de la Chontalpa sugar mill.

MATERIALS AND METHODS

The experiment was carried out under rainfed conditions, during the plant cycle in the supply area of "Santa Rosalía de la Chontalpa" sugar mill (ISRCH, in Spanish). Three sugarcane cultivars were used (CP 72-2086, MEX 79-431 and MEX 69-290). For this purpose, nine commercial plots (three for each cultivar) were located and georeferenced on a Eutric Fluvisol soil, with similar sowing dates. The local cooperating producers were responsible of the agronomic management of the crop. In each plantation, a sample with three replications (10 stems per replication) was collected, which were separated from sections 8-10. Stem samples and sections 8-10 were transported to the field laboratory of the ISRCH, where determination of the industrial quality of the samples was performed by polarimetry. Samplings were collected at 330, 390 days after sowing (DAS), and at harvest (450 DAS).

Experimental design and statistical analysis

The experiment had a 3 × 3 factorial design (3 Cultivars × 3 DDS). The statistical analysis consisted of the analysis of variance (ANOVA) for the effect of Cultivar (Cv), DAS and the Cv × DAS interaction with a significance level of $P \leq 0.05$ and the Tukey multiple means comparison, using INFOSTAT version 2018. A non-linear regression analysis was run with the juice quality data, determining the curve that best adjusted to each situation.

RESULTS AND DISCUSSION

Brix degrees

No statistically significant differences were found among cultivars (Table 1), recorded mean values were between 15.23 and 15.85 °Brix, lower than the mean values of 20.4 - 21.3 °Brix observed by Pereira *et al*. (2017), during the harvest of four sugarcane cultivars in Brazil. The °Brix increased from 13.94 at 330 DDS to 17.28 at 450 DAS, the latter value being slightly lower than 18 °Brix established as the minimum optimal value in sugar cane, according to Salgado *et al*. (2003). CP 72-2086 cultivar shows a slight drop in °Brix at 450 DAS sampling (Figure 1), although this was not statistically significant. The highest values of °Brix were observed in the 450 DAS sampling, reaching an average of 17.28 °Brix, similar to 17.15 and 17.86 °Brix reported by Salgado *et al*. (2017) for CP 72-1210 and MEX 69-290 with a supply of 120 and 180 kg N ha^{-1}, respectively. But they were lower than 20.3 to 22.35 °Brix described by Clemente *et al*. (2018) for three sugarcane cultivars at 402 DAS.

POL (%)

According to the multiple comparison test of Tukey, the POL (%) among cultivars is similar, since it found no statistic difference between its (Table 1). The percentage of POL fluctuated between 12.5 to 13.43, which is considered adequate for sugarcane juice with good quality (Salgado *et al*., 2003). Regarding the sampling dates, the highest percentage of POL (14.92) was observed in the sampling collected at 450 DAS, being lower than 18.53 to 19.75%

described by Clemente *et al*. (2018), for cultivars RB991536, RB011941 and RB92579 at 402 DAS.

The interaction between cultivars and sampling dates indicates that the percentage of POL was different between samplings at 330 and 390 DAS for MEX 69-290 and CP 72-2086, not finding differences between samplings at 390 and 450 DAS for those cultivars (Table 1). For MEX 79-431 a statistical difference was observed among three sampling dates, showing the highest percentage in the harvest, this can be explained by the sucrose accumulation process that occurs during the maturity stage of the sugarcane. The mean values presented by the cultivars, in the sampling at 450 DAS were 13.98% for CP 72-2086 and 15.62% for MEX 69-290 and MEX 79-431, which are higher than 12.0 to 13.4% reported by Islam *et al*. (2011) for six sugarcane clones.

The °Brix and POL (%) of CP 72-2086, showed a slight decrease between sampling at 330 and 450 DDS, although

Table 1. Analysis of variance and Tukey mean test of juice quality in three sugarcane cultivars, during the plant cycle in the ISRCH supply area.

Interaction Cv × DAS	DAS	MEX 69-290	CP 72-2086	MEX 79-431	Mean DAS†
°Brix	330	14.21 abc	14.17 ab	13.44 a	13.94 A
	390	15.57 bcde	16.32 cdef	14.84 abcd	15.58 B
	450	17.77 f	16.64 def	17.42 ef	17.28 C
	Mean Cv	15.23a	15.71a	15.85a	
POL (%)	330	11.84 ab	12.01 ab	10.51 a	11.45 A
	390	12.82 cd	14.17 cd	11.83 ab	12.94 B
	450	15.62 d	13.98 bcd	15.62 d	14.92 C
	Mean Cv	13.43b	13.39ab	12.5b	
Fiber (%)	330	11.99 ab	12.08 ab	11.42 a	11.83 A
	390	12.76 ab	12.99 b	11.83 ab	12.30 AB
	450	12.69 ab	11.48 a	12.73 ab	12.53 B
	Mean Cv	12.48a	12.18a	11.99a	
Purity (%)	330	83.24 abc	84.66 bc	78.13 a	82.01 A
	390	84.59 bc	84.57 bc	79.85 ab	83.0 A
	450	87.92 c	84.00 bc	87.41 c	86.44 B
	Mean Cv	85.25b	84.41b	81.80a	
Humidity (%)	330	82.9 b	81.24 b	83.68 b	82.61 B
	390	74.47 a	75.38 a	76.73 a	75.53 A
	450	74.52 a	75.48 a	73.37 a	74.46 A
	Mean Cv	77.29a	77.37a	77.93a	
Reducing sugars (%)	330	0.76 b	0.63 ab	0.76 b	0.72 B
	390	0.60 ab	0.55 ab	0.59 ab	0.58 A
	450	0.47 a	0.57 ab	0.53 ab	0.52 A
	Mean Cv	0.61 a	0.58 a	0.63 a	

	Probability of F for:			C. V (%)
	Cv	DAS	Interaction Cv × DAS	
°Brix	0.2424 NS	0.0001**	0.1850 NS	8.41
POL	0.0317*	0.0001**	0.0070*	10.24
Fiber	0.1726 NS	0.0176*	0.0099*	7.24
Purity	0.0016*	0.0001**	0.0027*	3.88
Humidity	0.5263 NS	0.0001**	0.0220*	2.65
Reducing sugars	0.6707 NS	0.0006**	0.4227 NS	26.66

†Cv=Cultivars, DAS= days after sowing, C. V.= coefficient of variation. Means with a letter in common do not present statistical difference ($P \leq 0.05$). Lowercase letters represent differences horizontally and uppercase letters do it vertically.

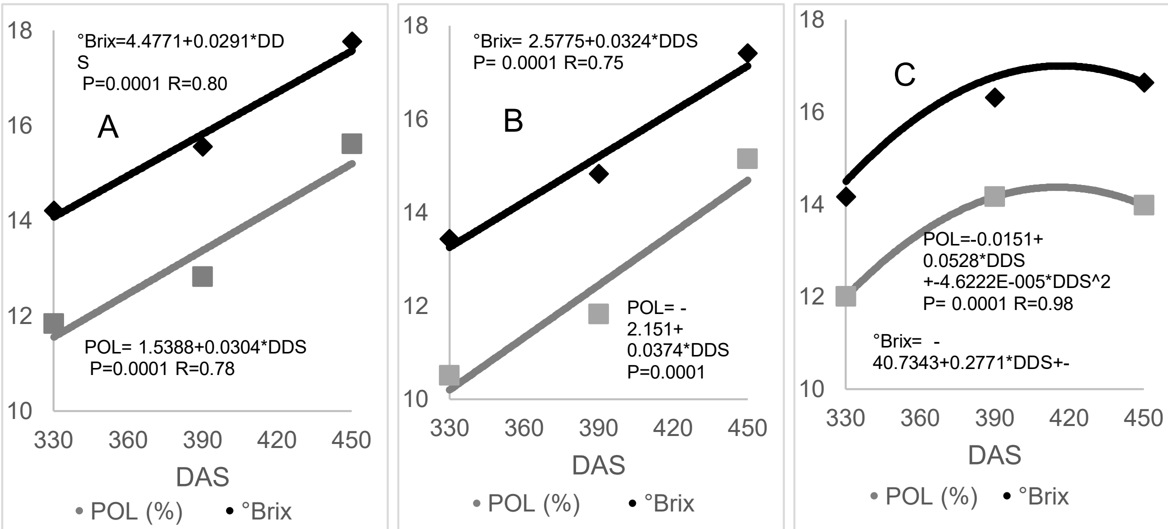

Figure 1. Accumulation dynamics of °Brix and POL (%) for sugarcane cultivars A) MEX 69-290, B) and C MEX 79-431) CP 72-2086 during the plant cycle in the supply area of ISRCH.

this was not significant. The trend line that was best adjusted for these variables in cultivar CP 72-2086 was quadratic polynomial (Figure 1), and indicates decrease in °Brix and POL in that cultivar; while for MEX 69-290 and MEX 79-431 a linear polynomial trend line was better adjusted, indicating that °Brix and POL values did not decrease. In this regard, Rodríguez *et al*. (2015), when evaluating 38 introduced sugarcane cultivars in Cuba, determined that the second-degree polynomial equation was the best fit to model the maturity of sugarcane cultivars during the evaluated harvest period.

Purity (%)

The cultivar MEX 79-431, presented the lowest percentage of purity (81.80%) compared to cultivars MEX 69-290 (85.25%) and CP 72-2086 (84.41%), between which there was no statistically significant difference. Values were lower than 87.45 to 88.45%, those found by Clemente *et al*. (2018). Regarding the sampling dates, between 330 and 390 DAS, there was no significant statistical difference, but there was for the sampling collected at 450 DAS, where the highest percentage of purity was observed (Table 1). Values observed for purity ranged between 82.01 and 86.44% at the sampling dates, which are slightly lower than the 85.5 to 87.5% observed by Xiao *et al*. (2017) in Guangxi, China.

In Figure 2, accumulation dynamics of the purity percentage of

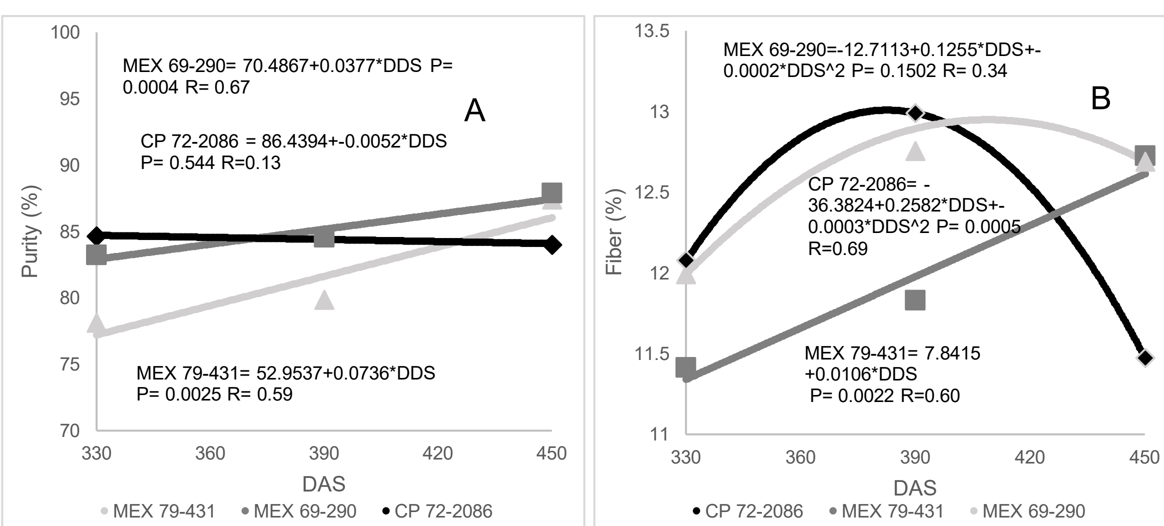

Figure 2. Dynamics of the percentage of (A) purity and (B) fiber of three cultivars of sugarcane during the plant cycle.

sugarcane cultivars can be observed throughout the maturity stage. The changing trend of purity (although without statistically significant differences) is clearly observed, expressing an increase from 330 DAS until harvest in cultivars MEX 69-290 and MEX 79-431.

The trend line that showed the best fit to the purity values (%) was a linear polynomial, although this was not significant for CP 72-2086 (Figure 2A). The mean purity values (%) observed in the sampling at 450 DAS for the three cultivars (84.00 to 87.92%), are slightly lower than those of 85.9 to 89.3% reported by Islam *et al*. (2011), for six sugarcane cultivars in Bangladesh.

Fiber (%)

For the fiber percentage, there was a statistically significant difference for the effect of the sampling date and for the Cv × DAS interaction (Table 1). The values registered for the cultivars were between 11.99 and 12.48%, which are lower than the 13.2 to 13.5% reported by Clemente *et al*. (2018). Regarding the sampling date, the highest percentage of fiber (12.53%) was observed in the sampling at 450 DAS, although it was not statistically different from the one performed at 390 DAS (12.30%). While the lowest value (11.83%) was observed in the sampling at 330 DAS, being less than 13.08 to 14.0%, those described by Salgado *et al*. (2017) for 10 sugarcane cultivars supplied with 0, 120 and 180 kg N ha^{-1}.

The Cv × DAS interaction for the fiber percentage shows that for the cultivar MEX 69-290 and MEX 79-431, the fiber accumulation dynamics was similar, an increase was observed as the harvest approached, although this was not statistically different. In the case of the CP 72-2086 cultivar, a different dynamic is observed, since the fiber percentage decreased significantly from the sampling at 390 to that collected at 450 DAS. The curve that fits the best for the fiber percentage values is a quadratic polynomial in CP 72-2086 and MEX 69-290, while for MEX 79-431, a linear polynomial was the better fit (Figure 2B).

Humidity (%)

The humidity content percentage was not significantly different among cultivars. However, for the effect of the sampling date and the Cv × DAS interaction, a statistically significant difference was observed (Table 1). The humidity percentage was very similar among the cultivars, with values of 77.29 to 77.93%, which are higher than those reported by Salgado-García *et al*. (2014) who reported humidity percentage of 69.79 and 70.14% for cultivars CP 72-2086 and MEX 69-290, respectively.

Regarding the samplings, the one performed at 330 DAS presented a higher value for humidity content (82.61%), decreasing in the subsequent samplings, although without statistical differences between 390 DAS (75.53%) and 450 DAS (74.46%). The dynamics of the humidity percentage of the evaluated cultivars showed a tendency to decrease as the harvest date approaches, reaching values between 73.37 and 75.78% at 450 DAS, which, according to Salgado *et al*. (2013), are considered adequate. The trend line that presented the best fit for the data of humidity percentage in stems was an inverse polynomial (Figure 3A).

Reducing sugars (%)

No statistically significant difference was found among the cultivars for the variable reducing sugars (%). Regarding the sampling date, it is observed that the reducing sugars decreased in the evaluated plantations (Table 1) as the harvest approached, being that at 390 and 450 DAS, when the lowest percentage of reducing sugars was registered (0.58 and 0.52% respectively); while the highest value (0.72%) for reducing sugars was observed at 330 DAS.

In Figure 3B it can be seen that reducing sugars are high when sugarcane is immature and low when it is ripe for harvest. These results are similar to those reported by Xiao *et al*. (2017) who mentioned that, during the period from growth to maturity of sugarcane, after the sucrose produced by the leaves is transported to the stems, the proportion of growth in the form of reducing sugars gradually decreases, and sugar reduction increases significantly when sugarcane is overripe, especially when juice quality tends to decrease.

Although the values of reducing sugars were not statistically different, for the cultivar CP 72-2086, a slight increase in the percentage of reducing sugars was observed in the sampling at 450 DAS, which indicates that this cultivar in plant cycle should be harvested after 330 DAS but before 450 DAS. This feature shows that CP 72-2086 is an early maturing cultivar. MEX 69-290 and MEX 79-431 showed a behavior as cultivars of medium-late maturity. The trend line that presented the best fit for the data on the percentage of reducing sugars was an inverse polynomial (Figure 3B).

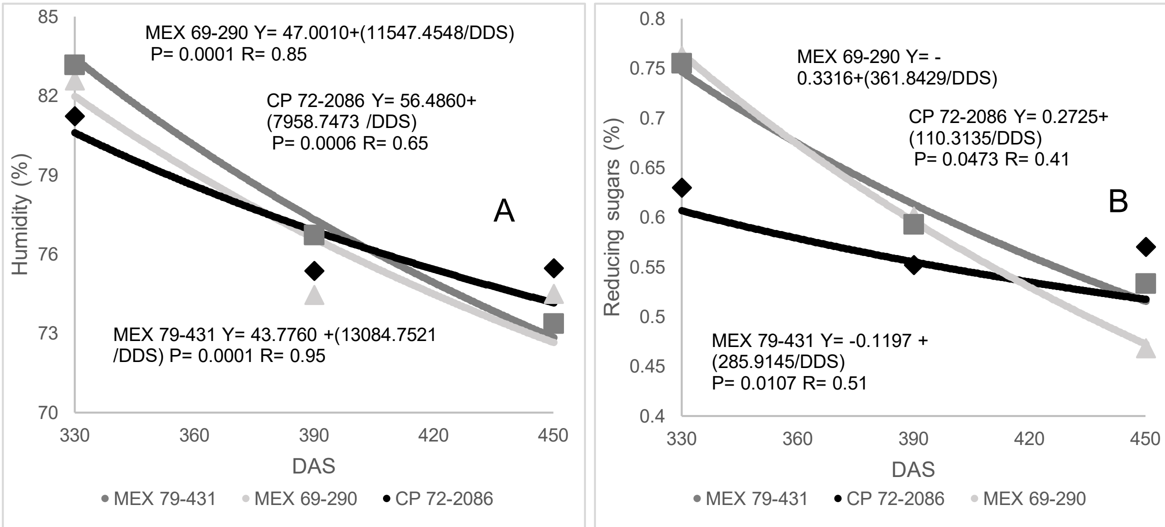

Figure 3. Dynamics of the percentage of (A) humidity and (B) reducing sugars, of three sugarcane cultivars during the plant cycle.

In Figure 1, it can be observed that the behavior of °Brix and the percentage of POL of the three evaluated sugarcane cultivars is similar, that is, as the °Brix increases or decreases, so does the percentage of POL and *vice versa*. This finding can be verified by the strong positive correlation presented between these variables (R=0.99 **; Table 2). Brix degrees presented a strong negative correlation with values of humidity percent and reducing sugars (R=−0.91 ** and R=−0.95 **, respectively), indicating that high °Brix values correspond to low values of humidity content and reducing sugars.

On the other hand, humidity percentage was strongly and positively correlated with the percentage of reducing sugars (R=0.91 **). In this regard, Salgado *et al*. (2016) observed that the lower the humidity in the stem, the less contents of reducing sugars.

CONCLUSIONS

Industrial quality of the evaluated cultivars only differed statistically in terms of the percentage of purity, with MEX 79-431 being the cultivar that presented the lowest value for this variable (81.80%); compared to MEX 69-290 (85.25%) and CP 72-2086 (84.41%) between which no statistically significant difference was observed.

In the sampling at 450 DAS, the highest value for °Brix (17.28), POL percentage (14.92%) and purity (86.44%) was observed. For the percentage of fiber, humidity and reducing sugars, no statistically significant difference was found between those samplings collected at 390 and 450 DAS. Values obtained in this study for the juice quality in the evaluated cultivars are within the range of standard values established in Mexico.

The trend line that best fitted the data for °Brix, POL and purity in MEX 69-290 and MEX 79-431 was a linear polynomial, while in CP 72-2086 it was a quadratic polynomial. Fiber percentage in CP 72-2086 and MEX 69-290 was best fitted with a quadratic polynomial trend

Table 2. Pearson's correlation coefficients (P≤0.05) between pairs of variables of juice quality (%) in three sugarcane cultivars during the plant cycle.

	°Brix (%)	Humidity (%)	Reducing sugars (%)	Fiber (%)	Purity (%)	POL (%)
°Brix	1	**	**	**	**	**
Humidity (%)	−0.91	1	**	**	**	**
Reducing sugars (%)	−0.95	0.91	1	**	**	**
Fiber (%)	0.66	−0.47	−0.54	1	**	**
Purity (%)	0.79	−0.71	−0.73	0.84	1	**
POL (%)	0.99	−0.91	−0.94	0.71	0.86	1

** highly significant (P≤0.05).

line and in MEX 79-431 with a linear polynomial. For the data of humidity percentage and reducing sugars, the trend line that best fitted was an inverse polynomial. Brix degrees (°Brix) presented a strong and positive correlation with POL (R=0.99 **) and strong and negative correlation with humidity percentage and reducing sugars (R=−0.91 ** and R=−0.95 **, respectively).

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