

ENERGY CONTENT: A NEW APPROACH TO CANE EVALUATION

By

L. CORCODEL and C. ROUSSEL

*eRcane, BP 315 La Bretagne,
97494 Sainte Clotilde, Reunion Island, France*

corcodel@ercane.re

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Abstract

IN RECENT years, the sugarcane industry has been moving from sugar production alone to sugar and energy production with the development of cogeneration and ethanol plants. Although cane fibre has always been considered a problem by the sugar millers, with increasing energy prices, fibre is becoming a major co-product of cane. The energy balance between sugar losses and energy production was evaluated for conventional cane and a new high fibre cane. The energy content of cane and cane products was calculated using their net calorific values. The results show that sugar is the main energy product recovered. Depending on their different uses, varietal comparisons based on energy content could be a new way of comparing sugarcane varieties. In Reunion Island, where cogeneration started in 1992, upcoming changes in French law on carbon credits are likely to modify the price of fibre for energy production in 2009. These changes will lead to the release of new cane varieties for sugar and electricity production, such as the promising eRcane elite cane R92/0804. A new approach to cane evaluation can therefore be based on the energy content of cane.

Introduction

The energy content of sugarcane offers a new approach to cane evaluation. Sugarcane bagasse is now regarded as 'bioenergy' and its value can be compared to that of coal. However, to fully exploit the value of bagasse, it is important to change strategies from sugar production alone to sugar and energy production.

This will lead to major changes in the sugarcane industry, such as grower payments for sugar and for fibre, and new varieties with higher levels of sugar and fibre. Cane energy content and energy yield per hectare and per tonne of cane will therefore become important parameters (Botha, 2009). Cane varieties should therefore be optimised for maximum energy production (Lima Verde Leal, 2007).

A new cane variety (R92/0804) that combines high fibre and sugar content has been developed in Reunion Island by eRcane. This variety was crossed (R575 × H72/8597) in 1992 and is now at the end of the breeding program. Agronomical results of five regional trials based on plant cane and two ratoons are presented in Table 1.

The two main varieties cultivated in Reunion, R570 (released in 1978) and R579 (released in 1993), were used as standards for the trials. Compared to the R579 standard, R92/0804 clearly gave better yields (+44%) with slightly lower sugar content in the cane (-3.6%) but a 29% increase in fibre content. Therefore, the overall increase in sugar yield per hectare is around 30%. This new variety appears to be promising in terms of tonnes of sugar per hectare, but the high fibre content should also be taken into account from the millers' point of view.

Table 1—Agronomical results of R92/0804 based on five regional trials (Plant cane + two ratoons),

	Yield/ha		Sugar in cane		Fibre in cane		Purity		Tonnes of sugar per hectare	
	tonnes	%/R579	% Cane	%/R579	% Cane	%/R579	%	%/R579	tonnes	%/R579
R570	82.52	-6.2%	12.99	-0.5	16.52	11.9	89.60	0.1	10.72	-7.0
R579	88.09	-	13.09	0.0	14.77	-	89.50	0.0	11.53	-
R92/0804	123.23	44.2	12.60	-3.6	19.02	28.9	88.80	-0.8	15.52	34.6

The objective was to add an indication of potential energy production to the traditional agronomic comparisons based on sugar yield per hectare. This potential energy production should be linked to the total energy content of cane, which can be divided into three elements: energy in fibre, energy in ethanol and energy in sugar crystals. This study was undertaken to assess the impact of different varieties on the energy recovered in terms of electricity, ethanol and sugar.

Calculation methodology based on net calorific value of products

This case is an example of what can be done on the basis of energy content in a country such as Reunion Island, with cane that mainly produces sugar, but also cogenerates electricity and produces rum from molasses.

The energy content of sugarcane and cane products was calculated using net calorific value. Net calorific value (NCV) is more practical than gross calorific value because it does not take into account the latent heat of the vapour. The NCV can be calculated from the chemical reaction on combustion.

The NCV of the sugarcane was calculated as the sum of the net calorific values of fibre, sucrose, glucose and fructose. The net calorific value of the cane fibre was calculated from a bagasse equivalent energy: bagasse weight as twice the cane fibre content and bagasse net calorific value of 4.23 kWh/kg (assumptions made for bagasse composition were 50% moisture, 1.2% ash content and 2.6 brix) with the SASTA Laboratory Manual (Anon, 2005).

The net calorific values of reducing sugars (glucose and fructose), ethanol and sucrose were 3.17, 6.20 and 3.56 kWh/kg respectively.

Cane and cane product energy content

Traditional agronomic comparisons of sugarcane are based on extractable sucrose. A simple method for estimating extractable sucrose is to deduct the sugar in the bagasse and the molasses from the sugar in the cane; mud and undetermined losses are not taken into account.

$$\text{Extractable sugar} = \text{Sugar in cane} - \text{Sugar in bagasse} - \text{Sugar in molasses}$$

Net calorific value was used to convert the weight of bagasse, ethanol and extractable sugar into energy.

Net energy content of sugarcane in Reunion Island conditions

The energy content of cane was calculated according to the fibre, reducing sugars and sucrose contents from the agronomic trials (Table 2).

Table 2—Net energy content of sugarcane in Reunion Island conditions.

	Net energy content of cane	
	kWh/t	kWh/ha
R570	1169	96 464
R579	1100	96 868
R92/0804	1261	155 336

Fibre in cane increases bagasse losses but also electricity production

Bagasse weight is directly affected by the fibre content of the cane and by bagasse moisture. Pol in bagasse is assumed to be a result of the milling operation. In sugar mills, sugar losses in bagasse are calculated using the following equation:

$$\text{Sugar lost in bagasse (t sugar / 100 t cane)} = \text{Bagasse weight} \times \text{pol\%bagasse}$$

It can be assumed that, with satisfactory milling operations, bagasse moisture and pol in bagasse can be maintained respectively at 50% and 1%. Hence, the previous equation can be simplified to:

$$\text{Sugar lost in bagasse} = \frac{\text{Fibre\%cane}}{50\%} \times 1\%$$

$$\text{Sugar lost in bagasse} = 2\% \times \text{Fibre\%cane}$$

This assumption oversimplifies reality but can be used as an easy method. Therefore, with an increase of cane fibre content, sugar lost in bagasse will increase as indicated in Table 3.

Energy from electrical production with bagasse can be estimated with the power delivered by the cogeneration plant to the electrical network.

Cogeneration and power production has been carried out in Reunion Island since the first installation of 80 bar boilers at Bois Rouge Mill in 1992. The cogeneration plants at the two factories in Reunion have two 30 MW turbines in Bois Rouge and two 32 MW turbines in Le Gol. Electricity produced with bagasse in Reunion has a ratio of 0.52 MWh/tonne of wet bagasse (ARER, 2008).

This ratio takes into account sugar mill steam and electrical power consumption. Based on cane fibre content, electricity production can be estimated using this ratio as indicated in Table 3.

Table 3—Fibre in cane increases bagasse losses but also electricity production
(For bagasse pol = 1% and bagasse moisture = 50%).

	Fibre in cane % cane	Sugar in bagasse % cane	Electricity Production KWh/t cane
R570	16.52	0.33	172
R579	14.77	0.30	154
R92/0804	19.02	0.38	198

Sugar in molasses increases losses in molasses but also ethanol production

The sugar content in molasses can be estimated using the SJM formula with a molasses standard purity of 40 (Table 4).

The total fermentable sugar content was calculated with the results of sugar content in molasses and with an average reducing sugar content in molasses of 7.7% (Reunion average for 2008 crops).

This total fermentable sugar content can be used to estimate ethanol production based on Pasteur Yield (643 L of alcohol / tonne of sucrose) and average distillery performance (86%) as presented in the equation below. Ethanol was converted into kWh with density data (0.791 kg/L) and net calorific value.

$$\text{Ethanol yield (L/100 t cane)} = \text{Molasses\%Cane} \times \text{Total fermentable sugar\%molasses} \times 643 \times 86\%$$

Ethanol production does not appear to be affected by variety (Table 4). Varietal comparison based on ethanol yield in L/100 t cane or in kWh/t cane is close for the three varieties tested.

Table 4—Sugar in molasses increases losses in molasses but also increases ethanol production (% cane = tonnes sugar/100 tonnes of cane).

	Sugar in molasses % cane	Ethanol production	
		L/100 t cane	kWh/t cane
R570	1.01	611	30
R579	1.02	630	31
R92/0804	1.06	643	32

Extractable sugar can be converted into energy

The extractable sugar can be calculated from the sugar in cane minus bagasse losses minus sugar in molasses. This extractable sugar can be converted into energy content with the sucrose, glucose and fructose net calorific values, as presented in Table 5. In these trials, R92/0804 has the lowest level of extractable sugar but, due to the high yield per hectare, sugar production is increased by 32%.

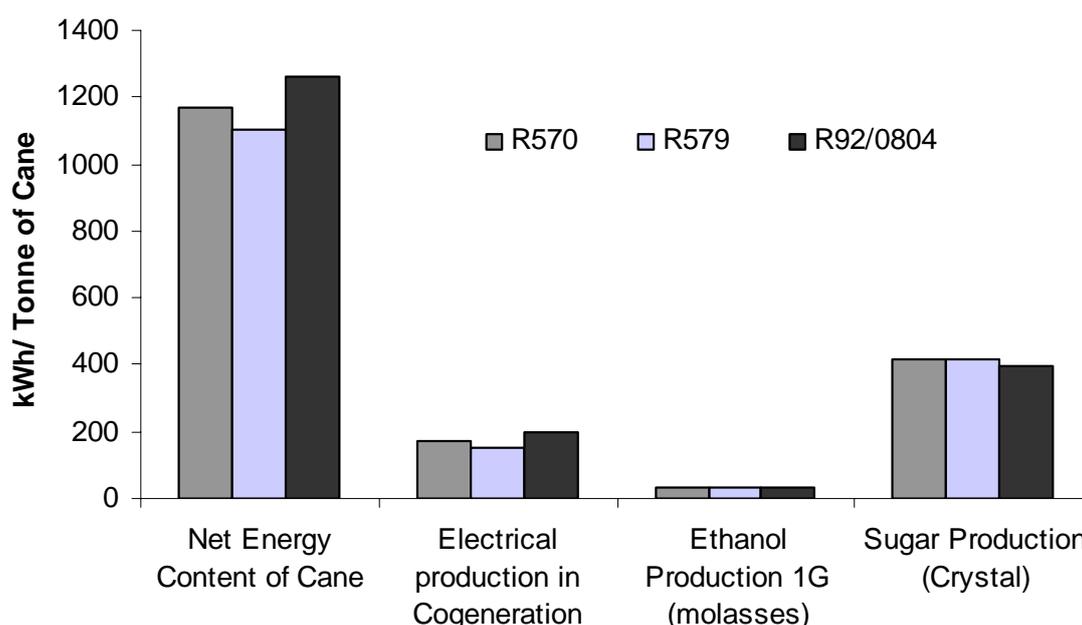
Table 5—Extractable sugar is energy (% cane = tonnes sugar/100 tonnes of cane).

	Extractable sugar		Extractable sugar	
	% cane	kWh/t cane	t/ha	kWh/ha
R570	11.66	414	9.62	34 198
R579	11.77	418	10.37	36 857
R92/0804	11.16	397	13.75	48 880

Energy based varietal comparison

Energy based varietal comparisons can be made using the net energy content of the cane and the energy recovered in electrical production, ethanol and in sugar crystals.

Results show that sugar is the main energy product recovered (35%) from sugarcane (Figure 1). Energy recovered in electricity and ethanol represents respectively around 15% and 3% of the energy content of the cane.

**Fig. 1**—Varietal comparison based on energy content per tonne of cane.

Results per hectare also show that sugar is the main energy product recovered from sugarcane (Figure 2). According to the agronomic results presented in Table 1, R92/0804 has 34.6% higher yields than R570 and R579 and this leads to greater differences in terms of cane energy content and energy recovered in the different products.

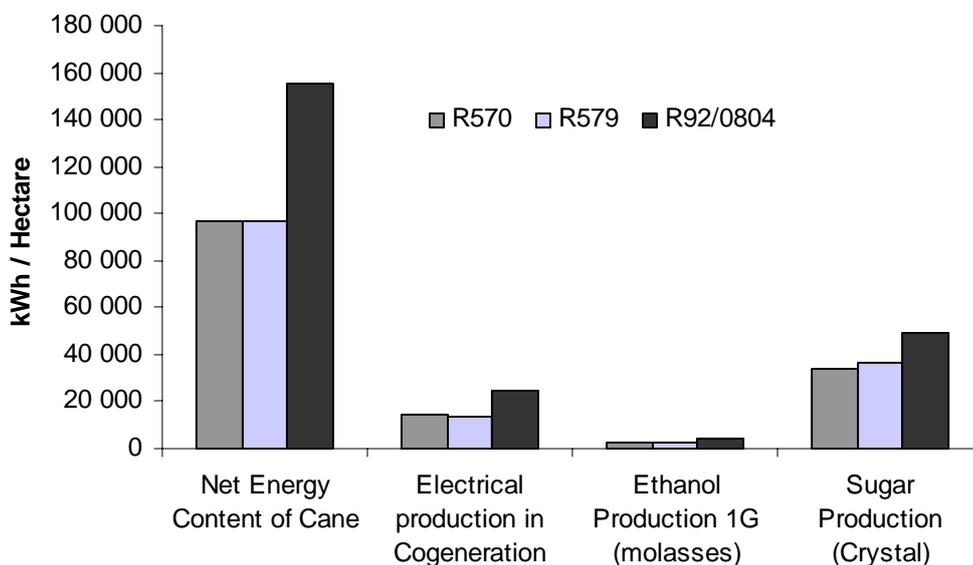


Fig. 2—Varietal comparison based on energy content per hectare.

Current process efficiencies lead to high energy losses between cane energy content and energy recovered. The total energy recovered for R570, R579 and R92/0804 is 50, 52 and 47% respectively.

There are clearly varietal differences and R92/0804 has the highest potential for electrical, ethanol and sugar production compared to the two other varieties. R570 and R579 have the same net energy content per hectare, but R570 appears to produce more electricity and less sugar compared to R579.

A possible limitation of this paper stems from the assumptions made for the calculations (extractable sugar, ethanol and cogeneration yields). The figures could also be completed with data on energy consumption during processing, which varies depending on cane composition.

This new approach to cane energy content highlights that sugar is the main energy component of sugarcane. A practical application for breeders is to develop new selection schemes to increase fibre and sugar content. As for millers, depending on energy prices, the traditional sugar losses can now be seen in terms of energy and economic gains.

Conclusions

This new approach to cane evaluation based on cane energy content highlights that sugar is the main energy component of sugarcane. All the parameters presented in this paper can be used on a large scale to compare different cane varieties using existing parameters. Future improvements call for the development of new parameters to replace the different theoretical ratios used at present. All the theoretical assumptions must be proved experimentally and measured in order to assess the overall impact of high fibre cane on sugar processing.

These preliminary results show that R92/0804 can increase the overall energy content, which will result in an increase in sugar and electricity production. Sugar processing is likely to be affected with an increase in sugar losses.

In Reunion Island, the sugarcane industry is moving forward. Bagasse now has value, which

will be paid to the growers for the 2009 crop. The exact payment method is still under study, but it is a sign that sugarcane will no longer be cultivated for sugar alone. This new value will be a complement to the sugar value, which is still the main energy component of cane.

When new varieties with higher levels of sugar and fibre are released, this will have an impact on sugar mills' performance. Further research is required to evaluate this impact.

Acknowledgment

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CONTENU ENERGETIQUE: UNE NOUVELLE APPROCHE POUR L'EVALUATION DE LA CANNE

Par

L. CORCODEL et C. ROUSSEL

*eRcane, BP 315 La Bretagne,
97494 Sainte Clotilde, Reunion Island, France
corcodel@ercane.re*

**MOTS CLÉS: Énergie, Coproduits,
Fibre, Cogénération, Qualité.**

Résumé

DEPUIS plusieurs années, l'industrie cannière a évolué d'une extraction du sucre à du sucre et une production énergétique avec le développement de la cogénération et des distilleries d'éthanol. La fibre de la canne a toujours été considérée comme un problème par l'industriel sucrier. Avec l'augmentation du prix de l'électricité, la fibre devient un coproduit majeur de la canne. La balance de l'impact de la fibre sur les pertes en sucre et la production énergétique a été évaluée. Ce document compare les impacts des cannes à forte fibre sur les procédés sur une base de bilan énergétique. Selon les débouchés, la comparaison variétale sur des bases énergétiques peut être une nouvelle façon de sélectionner des cannes. À La Réunion, la cogénération a débuté en 1992 et les futurs changements liés aux lois françaises et aux crédits carbone vont modifier le prix de l'énergie en 2009. Ces changements vont conduire à libérer des nouvelles variétés pour la production sucrière et électrique comme l'élite prometteuse d'eRcane la R92/0804. Une nouvelle approche pour l'évaluation des cannes peut être basée sur le contenu énergétique de la canne. Le contenu énergétique de la canne et de ses coproduits a été calculé en utilisant leur pouvoir calorifique inférieur.

CONTENIDO DE ENERGÍA: UN NUEVO ENFOQUE PARA LA EVALUACIÓN DE LA CAÑA

Por

L. CORCODEL and C. ROUSSEL

eRcane, BP 315 La Bretagne, 97494 Sainte Clotilde, Reunion Island – France
corcodel@ercane.re

**PALABRAS CLAVE: Energía, Co-Productos,
Fibra, Cogeneración, Calidad.**

Resumen

EN AÑOS recientes, la industria de la caña de azúcar se ha estado moviendo de la producción de azúcar únicamente, a la producción de azúcar y energía con el desarrollo de la cogeneración y las plantas de etanol. Aunque la fibra en caña ha sido siempre considerada un problema por los operadores de molienda, con los precios crecientes de la energía la fibra se está convirtiendo en un co-producto principal de la caña. El balance de energía entre pérdidas de sacarosa y producción de energía fue evaluado para caña convencional y nuevas cañas altas en fibra. El contenido de energía de la caña y sus productos fue calculado usando sus valores caloríficos netos. Los resultados mostraron que el azúcar es el principal producto energético recuperado. Dependiendo de sus diferentes usos, las comparaciones varietales basadas en su contenido energético podrían ser una nueva forma de comparar variedades de caña. En la isla Reunión, donde la cogeneración inició en 1992, se avecinan cambios en la ley francesa sobre créditos de carbono que podrían modificar el precio de la fibra para producción de energía en 2009. Estos cambios llevarán a la liberación de nuevas variedades de caña para azúcar y para producción de energía, como la promisorio variedad de élite R92/0804. Un nuevo enfoque para la evaluación de variedades podría estar basado en el contenido energético de la caña.