

THE EFFECT OF GREEN CANE HARVESTING ON A SUGAR MILL

By

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Abstract

THE MAIN consequence of processing green cane is expected to be an increase in the quantity of leaves and tops accompanying the cane. This affects recovery of sugar, the effective capacity of the mill and milling costs. Other consequences such as the potential for receiving fresher cane are considered. An attempt is made to estimate the magnitude of some of these effects. There are two scenarios to consider. In the more common case, the objective is to produce clean fresh cane and the issue is managing the extraneous matter content of the cane. In the second case, where a mill wishes to maximise the biomass input for cogeneration or by-product purposes, the leaves and tops have significant value and are required at the mill. To achieve maximum profitability in both cases, the options of incentives, cane payment system changes and separating the leaves and tops before processing are considered.

Introduction

The most noticeable effect of green cane harvesting is an increase in the amount of leaves and tops attached to the cane. This is an expected consequence if the harvesting procedures do not change when a change from burnt to green cane is made.

The effect of the higher trash content on the mill will be adverse, and it is expected that the miller would try to persuade the harvester to change his behaviour to produce cleaner cane. The incentive that needs to be provided should be related to benefits obtained from cleaner cane.

In the first instance, there is a need to assess the effect of extraneous matter in cane, both quality and quantity, on factory processing.

The effects of green cane harvesting need not all be adverse. Abandoning burning leads to more flexibility in harvesting and also to fresher cane of potentially better quality. In addition, any mill that employs cogeneration or requires more fuel because of downstream by-product activities will benefit from the fuel value of the tops and leaves.

The response to the change to green cane has to be well-considered, to derive maximum profitability in the changed circumstances.

Quantity and quality of trash in cane

The quantity of trash depends on the moisture content of the trash, and particularly the proportion of dry leaves in the trash. For instance, Ivin and Doyle (1989) measured the tops and leaves in whole cane and found that they represented 18.8 g/100 g of the total cane mass. Schembri *et al.* (2002) report a level of tops and leaves of 20 to 35 g/100 g total cane.

The amount of tops and leaves is better represented in terms of dry matter in relation to the amount of cane, because this measure is independent of the moisture content of the tops and leaves.

Leaves and tops expressed on a dry matter basis have been estimated in Brazil to average 140 kg dry matter / t of whole stalk cane, varying between 110 and 170 kg/t cane (Hassuani, 2001).

Purchase and de Beer (1999) report that tops and leaves represent on average 190 kg dry matter / t mature clean cane stalk. An average of about 150 kg dry matter in leaves and tops/100 kg clean whole stalk cane can be assumed.

This number suggests that leaves and tops can potentially double the amount of fuel available for power generation, a conclusion substantiated by Schembri *et al.* (2002). In practice, the efficiency of recovery of this material from the fields varies between 56% and 84% (Hassuani, 2001).

The quantity of trash in cane delivered to the mill depends on the efficiency of trash removal during harvesting and whether the cane is burnt or harvested green. Legendre *et al.* (1999) reported leaves and tops content varying between 10 and 17 g/100 g green cane, depending on harvester extractor fan speed.

The numbers were slightly lower for burnt cane, varying from 8 to 11 g/100 g. Hand cut and topped burnt cane had a lower trash content of 6 g/100 g cane. Scott (1977) reported figures for cane delivered to Huletts mills in South Africa of 5.7 g/100 g burnt cane and 11.0 g/100 g hand-trashed cane.

Birkett (1965) reported tops and leaves to be 16.5 g/100 g of the total mass of cane. Larrahondo *et al.* (2004) reported extraneous matter in hand cut and mechanically harvested green cane in Colombia of 5.9 and 12.4 g/100 g cane, respectively.

The composition of tops and trash has been measured by a few different groups in various cane growing areas (Scott, 1977; Scott *et al.*, 1978; Ivin and Doyle, 1989; Birkett 1965).

At Audubon Sugar Institute, tops and trash have been analysed over the past few years in an attempt to characterise the material for research aimed at extracting more value from the trash (Saska and Gil, 2004).

All these results show high fibre content and low juice sucrose purity in the trash. These data are useful in predicting the effect on the composition of cane containing various amounts of trashy material.

Effects of green cane harvesting

It is of interest to consider the effects of green cane harvesting on the miller. The advantages are:

- Cane is fresher when it reaches the mill and has a lower dextran and impurity content.
- It degrades more slowly in storage.
- In bad weather, there is more flexibility in choosing fields to harvest.
- It leads to more fuel or more biomass, which can be an advantage or disadvantage depending on the situation of the mill.

There are a number of disadvantages, however:

- There is more material to process.
- The higher fibre content means that there is a greater loss of sugar in bagasse.
- More molasses is produced as a result of the lower purity and a higher loss of sugar in molasses results.
- The sugar colour is affected adversely.
- There is more starch in the juice because of the higher starch content of the trash.
- Milling costs depend on cane crushed and revenue depends on sugar produced; trash inflates the former and reduces the latter.
- The bulk density of the cane in the transport vehicles is considerably lower.

Elements dictating the value of cane delivered to mill

The way in which trashy cane affects processing needs to be understood. Some cane payment schemes take into account the recoverability of sugar in cane, but that is only one of three components that have a material effect on processing. These three components are:

Recovery

The recoverable sugar content of cane is affected by the purity and fibre content of the cane. A higher fibre content increases the amount of bagasse and the sugar lost in the bagasse. A lower purity increases the nonsucrose input into the factory, increasing the quantity of molasses and the loss of sucrose in molasses. The magnitude of both these effects can be calculated.

Cost of processing the cane

Processing costs are determined by the tonnes of cane processed. If the mill has to process more cane (because of the trash content) to produce the same amount of sugar, milling costs will go up correspondingly. The need to deal with a higher coloured juice, perhaps containing more starch, will also increase costs.

In addition, trashy cane has associated with it more field soil that increases the cost of maintenance, reduces the output of the boilers, and leads to higher usage of supplementary fuels.

Effect on capacity of the mill

In designing a sugar mill, the fibre content of the cane or the total amount of fibre to be handled determines the extraction plant size; the total sucrose input determines the sizing of the high grade pan station; and the nonsucrose input into the mill sets the capacity of the low grade pan and centrifugal station.

Changes in cane quality are reflected in the changes in fibre and nonsucrose in the cane. Cane with excessive trash will increase both these inputs significantly. Deterioration of one of these cane quality parameters can restrict throughput and may lead to a situation where one part of the factory becomes a bottleneck while there is surplus capacity elsewhere in the factory.

In the case of maximising biomass, there would still be a desire to receive high purity juice in cane. In this case the mill has to decide whether to process the leaves and tops with the cane or to separate this material before processing.

Effect of tops and leaves on capacity and recovery

Work was undertaken in Australia that illustrates very well the effect of clean and trashy cane on the whole operation of harvesting, transport, and processing (Kent *et al.*, 2003). The effect on transport and crushing rate is shown in Table 1 and the effect on juice quality in Table 2.

Table 1—Results from an investigation into the effect of trash in cane (Kent *et al.*, 2003).

Trash level	Extraneous matter (g/100 g cane)	Leaves and tops (g/100 g cane)	Bin weight (t)	Crush rate (t/h)	Fibre rate (t/h)	Recoverable sugar (g CCS/100 g cane)
High	15.1	12.7	7.3	306	46.7	12.8
Low	6.4	5.9	8.6	351	45.7	14.0

Table 2—Effect of trash on juice quality (Kent *et al.*, 2003).

Trash level	Purity	Reducing sugars (g/100 g solids)	Ash (g/100 g solids)	Colour (IU)
High	89.9	4.0	2.7	15 400
Low	91.5	3.6	2.2	11 800

The data of Reid and Lionnet (1989) also show that the presence of trash reduces the purity of the juice significantly. Leaves increase the fibre content by 47% and the ash content by 62%. The tops have a less severe effect, marginally increasing the fibre, but increasing the ash by 36%.

Calculations using data given by Scott *et al.* (1978) show that adding tops to clean stalk does not significantly affect the fibre content, but reduces the juice purity by 0.3 units for every 1% of tops. Leaves, however, significantly increase the fibre content as well as reducing the juice purity to the same extent as tops. The presence of tops and leaves can reduce cane juice purity by up to 5 units.

It has been reported that a reduction of 1% trash in cane reduces the crushing rate by 3% (Scott, 1977). Work reported by Reid and Lionnet (1989) proved that excessive tops and trash results in a reduction in milling capacity. However, the fibre rate through the mills remained reasonably constant at the same mill speed; thus the reduction observed is due directly to the additional fibre that has to be processed. Data in Table 2 show that a reduction in trash and tops content of about 7% led to an increase in crushing rate of 15%, but the fibre crushing rate was virtually constant in this case too.

The data of Kent *et al.* (2003) in Table 1 and other data show that the presence of trash significantly reduces the bulk density. This has implications for the capacity of cane bins used in the cane yard and for cane conveyors which will have to accommodate a larger volumetric throughput.

A measure of the nonsucrose components in cane extracted into the juice is obtained from the juice purity. There is one other nonsucrose component which needs to be considered on its own, since it not only affects the loss in molasses but also severely affects the processing of the cane juice. This component is dextran, which is not a natural product in the cane, but a consequence of microbial action either in cane (particularly chopper-harvested) subject to long delays, or in the milling tandem itself. Since deterioration is faster in burnt than green cane, this effect is likely to be less severe with green cane harvesting.

Effect on cane freshness

Deterioration starts in burnt cane from the moment it is burnt, as the heat of the fire cracks the rind and exposes some juice. With unburnt cane, deterioration starts only when the cane is cut, at the cut ends.

Deterioration occurs more rapidly in chopper harvested cane, because there are many more exposed ends. The effect can be minimised by increasing the billet length and by ensuring that the cutters on the harvesters are sharp to get a clean cut; this ensures that the amount of juice exposed to the atmosphere is kept to a minimum.

Micro organisms in the soil or the air infect the exposed juice. Depending on the predominating organism, the products of micro organism activity may be some or all of dextran, ethanol, oligosaccharides, and organic acids. All of the micro organisms use sugar as a food, leading to direct and indirect losses of sucrose. The rate at which these organisms metabolise sucrose is also largely dependent on temperature and their activity is greatly reduced in cold weather. Wet conditions encourage the formation of dextran.

Where chopper harvesters are used, systems of transport must be able to keep the transport delay down to less than 16 hours. Above that time, dextran formation occurs to the extent that the processing of cane is impaired. In severe cases, dextran levels rise to above 1000 mg/kg solids and the pH of the juice drops below 5.

With whole stalk cane, deterioration is not as rapid and longer delays between burning and cutting and harvesting can be tolerated. A number of studies were done in South Africa to investigate the changes occurring in the cane after harvesting. The findings can be summarised as (Cox and Sahadeo, 1992):

- Ethanol is the most obvious degradation product, not dextran.
- Deterioration is more rapid in burnt cane than unburnt cane.
- Loss of recoverable sugar in cane averaged about 1% per day, although some much larger numbers have been reported.
- The cane juice purity dropped about 0.6 units each day. Lionnet (1986) showed reductions of between 0.4 and 2.5 units, depending on temperature.
- There is a loss in cane mass of 0.5–1.5% per day (this sometimes leads to the erroneous belief that sucrose in cane increases after harvesting).
- The degree of deterioration depended on whether the cane was windrowed or stacked in bundles.

Value of reduced trash in cane

As a result of lower trash levels, a reduction in season length can be calculated. Using the estimate of Scott (1977) that 1% trash reduces the grinding rate by 3%, for a mill crushing 2 million tonnes at 10 000 t/day, a reduction of 1% reduces the crop to 1 980 000 tonnes and the crushing rate increases to 10 300 t/day. Based on these figures, the season length becomes $1\,980\,000/10\,300 = 192.2$ days, a reduction of 7.8 days. The improvement in cane quality can be calculated from values reported in the literature. In total, a reduction of just 1% in the trash content of cane will lead to the following results:

- A reduced length of season, shortened by 1 week in a 200 day season.
- An increased juice purity of 0.4 units.
- A reduction in the cane fibre content of 0.1 units
- An increase in extraction of 0.1% and an increase in sugar production of 0.3%.
- An improvement in juice colour of about 3 to 4%.
- Reduced mill costs through crushing less cane, since costs are directly dependent on the mass of cane crushed.
- Less wear experienced in the factory.

These figures indicate that a reduction in 5 units of tops and trash, a feasible improvement, will lead to an additional 1.5% sugar being produced. This is a really substantial reward, particularly when considered together with the reduced season length. These calculations are based on reducing tops and leaves by equal amounts. If the reduction is achieved by reducing the leaf content rather than tops, the improvements in recovery noted above are even higher.

Value of reduced cane delays

It is common practice in some places to burn one evening and harvest the next day. Where whole stalk harvesting is practised, it is not uncommon for cane to be burnt more than one day ahead. Since there is a loss of 1% of recoverable sugar per day, burning ahead can be extremely costly.

If rain interferes with the cutting of previously burnt cane, the results can be very serious. Unfortunately the loss is not measured. In serious cases the most tangible evidence is high dextran or ethanol levels in the cane.

Thus the advantage of green cane harvesting in saving one day of cane delay between burning and harvesting is roughly the equivalent of reducing leaves and tops in cane by 3 g/100 g cane. Thus recovery would remain unaffected if the trash content increased by 3 units but the cane delay reduced by one day. This is a big advantage, often overlooked in comparing green cane and burnt cane harvesting. This also emphasises the point that fresh cane should be actively pursued in all circumstances.

In the event of cane delays for whatever reason, green cane will deteriorate more slowly than burnt cane.

Options for accommodating green cane

There is clear evidence to show that reduced trash in cane has substantial benefits and a change to green cane harvesting should not necessarily mean acceptance of a reduced cane quality. Some action is necessary, and the following options can be considered:

Appropriate incentives

Handling the trash associated with green cane leads to increased costs for the grower. Financial incentives would be necessary in the form of additional payments to the growers for good quality cane. These should come from the increased profits which accrue as a result.

This might mean that some additional measurements would be necessary to measure cane quality, perhaps using NIR measurements (Larrahondo *et al.*, 2004). Incentives should be related to the effect on sucrose recovery, milling costs and mill capacity:

- To account for the effect on recovery, the cane payment system should be based on a recoverable sugar formula.
- To account for the cost of processing cane with potentially high trash levels, payment to the millers for crushing the cane should be based on the tonnes of cane processed, allocating a fixed mass of recoverable sugar per tonne processed. This is the principle incorporated in the Australian cane payment system. If necessary, a penalty/bonus system to discourage field soil in cane should be considered as well.
- To account for the effect on capacity, consideration could be given to a bonus/penalty system on fibre and nonsucrose content of cane. High levels of dextran in cane (measured at the time the cane is received at the mill yard) should also be penalised. The development of a dextran 'dip stick' would make this possible (Day and Kim, 2004).

Single business entity

The business of growing and processing cane should be considered as a single business, and decisions on what to do should be taken on what is good for the combined growing and milling operation. The cane payment system and the incentives discussed above should be such as to encourage the optimum profitability of the enterprise as a whole.

A study by the two research institutes in Australia was undertaken jointly (Anon., 1998); a model was developed in which all major costs associated with the presence of trash in the cane supply were evaluated to determine the effect on total industry returns. They found an optimum return at a low level of trash in cane; the results are shown schematically in Figure 1.

The model indicated that 'a reduction in harvester pour rate will reduce the level of trash in the cane supply and produce an increase in net returns for the industry as a whole' (Anon., 1998). The optimum level of trash is likely to be different in different areas, depending on local cost structures.

Trash removal at the mill

In order to achieve the low level of tops and leaves required, the extraneous matter can either be removed in the fields or at the mill. It has been shown that most of the trash can be relatively easily removed from billeted cane at the mill by blowing the trash out of the cane as it dropped from one conveyor onto another (Rein, 2004). Results obtained are shown in Figure 2.

The interesting feature is that the separation was achieved with virtually no loss of billets, but the problem of how to dispose of the enormous bulk of trash that rapidly built up at the mill was insoluble. Pneumatic cleaning of cane in Australia has also shown that removal of trash with a low level of billet loss is possible (Schembri *et al.*, 2002).

The difficulty with this approach is assessing cane quality and rewarding it equitably. Analysis would have to be done on a hand cleaned sample or on the cane after a mill dry cleaning system, if installed. This may not be acceptable to all growers.

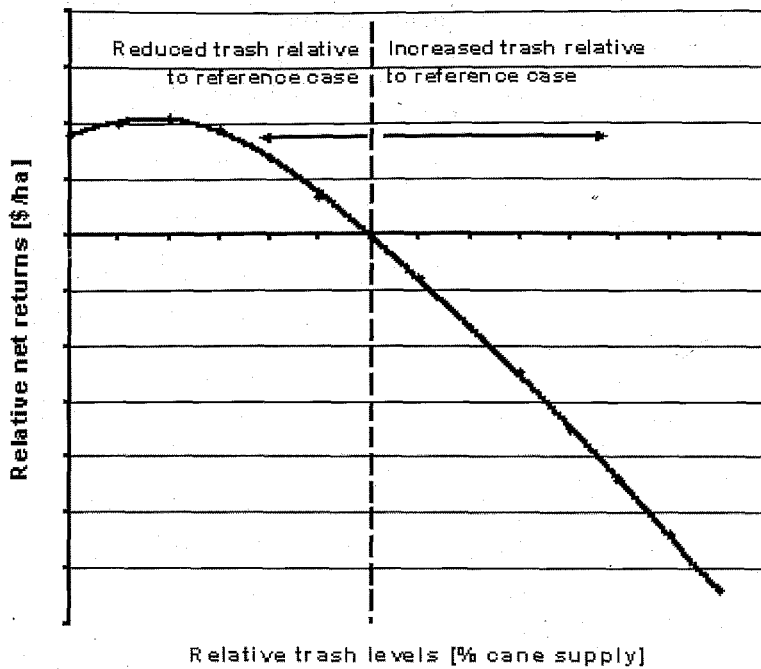


Fig. 1—Typical predicted trend for effects of trash on the net returns to the industry as a whole (Anon., 1998).

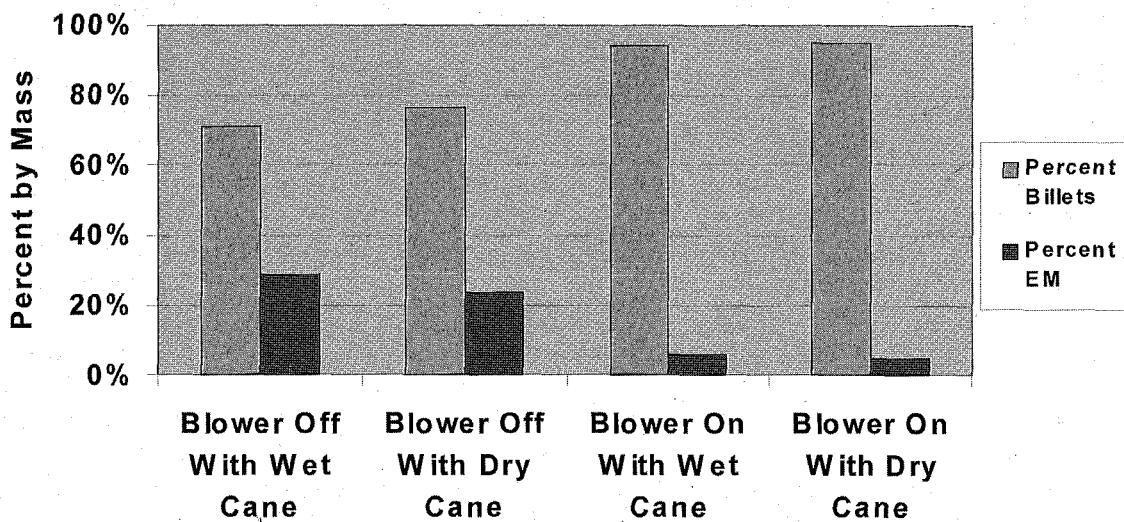


Fig. 2—Extraneous matter (EM) removal by blowing from billeted cane at Enterprise mill (Rein, 2004).

Use of tops and leaves for cogeneration or by-product purposes

In most situations, the quantity of bagasse available can be increased by more than 50% by utilising the whole cane stalk. If cogeneration is practised or surplus bagasse can be profitably used, the leaves and tops must be transported to the mill either with the cane or after separation in the fields. In the former case, it will be desirable to separate the tops and leaves before processing. The decision on which approach to adopt would be a purely economic one. Hassuani (2001) reports that, for Brazilian conditions, it is less costly to remove the trash in the field and bring it to the mill in bales than to separate trash at the

mill. It should be possible in many sugar industries around the world to obtain revenue from cogeneration or by-products to more than cover the cost of processing the whole cane. This is in fact the case in places like Guatemala, Mauritius and India, where cogeneration is practised. It is necessary, however, to burn the trash with bagasse in the boilers; attempts to burn the leaves and tops on their own are expected to lead to slagging and fouling problems in a sugar mill boiler due to the high ratio of alkali metals to silica (Magasiner *et al.*, 2001).

Conclusions

It is likely that the extraneous matter content of green cane delivered to the mill will be higher than that of burnt cane, unless incentives are in place to reduce the amount of leaves and tops included in the cane. The effect on recovery of sugar, effective mill capacity and milling costs can be quite serious. The introduction of a cane payment system that encourages good quality cane and is based on a milling fee per tonne of cane is highly desirable. An advantage of green cane harvesting that could be quite considerable, particularly in bad weather conditions, is that less deterioration of cane prior to crushing can be expected.

Mills involved in cogeneration need to consider whether to bring all the cane to the factory and separate the leaves and tops prior to crushing, or whether to leave the trash in the fields and bring it in separately. Leaves and tops can be removed from chopper-harvested cane at the mill by a pneumatic separation system which has the advantage of low billet loss. This may be an option as well for mills not involved in cogeneration, providing a no-cost method of disposing of the trash removed can be found.

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L'EFFET DE LA RECOLTE EN VERT SUR UNE USINE SUCRIERE

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**MOTS CLÉS: Qualité de la Canne, Canne Récoltée en Vert,
Recouvrement du Sucre, Coûts d'Usinage.**

Résumé

L'USINAGE de la canne récoltée en vert aura pour conséquence majeure un apport d'une plus grande quantité de feuilles et de bouts blancs à l'usine. Ceci aura pour effet d'affecter le recouvrement du sucre, ainsi que la capacité réelle de la sucrerie et les coûts d'usinage. D'autres aspects tels que le potentiel de réception d'une canne plus fraîche sont aussi à l'étude. Par ailleurs, une estimation de l'ampleur de certains de ces effets est aussi tentée. Deux scénarios doivent être considérés. Dans le cas le plus courant, l'objectif est de produire une canne propre pour la récolte en vert et la question est de gérer la matière étrangère de cette canne. Dans l'autre scénario où l'usine voudrait maximiser son apport de biomasse pour les besoins de cogénération ou autres sous-produits, les feuilles et les bouts blancs représentent une valeur significative et sont requis à l'usine. Afin de réaliser le maximum de profit dans les deux cas, différentes options telles que des incitations, des systèmes de paiement modifiés et la séparation des feuilles et des bouts blancs d'avec la canne avant l'usinage sont considérées.

EL EFECTO DE LA COSECHA EN VERDE EN UN INGENIOAZUCARERO

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**PALABRAS CLAVE: Calidad de la Caña, Caña Verde,
Recuperación de Sacarosa, Costos de Molienda.**

Resumen

LA MAYOR consecuencia esperada de procesar caña verde es el aumento en la cantidad de hojas y cogollos que acompañan la caña. Esto afecta la recuperación de sacarosa, la capacidad efectiva del ingenio y los costos de molienda. Otras consecuencias como el potencial para recibir caña más fresca deben ser consideradas. Se ha hecho el intento estimar la magnitud de algunos de estos efectos. Hay dos escenarios a considerar. En el más común de los casos, el objetivo es producir caña limpia y fresca y el objeto es manejar el contenido de materia extraña de la caña. En el segundo caso, en el que un ingenio desea maximizar la entrada de biomasa para cogeneración o para otros sub productos, las hojas y cogollos tienen un valor significativo y son pedidos por los ingenios. Para alcanzar la máxima productividad en ambos casos, se consideran opciones de incentivos, cambios en los sistemas de pago de caña y separaciones de hojas y cogollos antes de la molienda.