

CANE TRASH AS FUEL

By

N. PRABHAKAR, D.V.L.N. RAJU and R. VIDYA SAGAR

Nava Bharat Ventures Ltd, Samalkot, India

np@nbv.in

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Abstract

SUGARCANE dry trash, a residue in cane fields, has significant potential as a biomass fuel. It contains nearly 28% of the total energy content in the sugarcane crop. However, this potential fuel is wasted by burning it in open fields after sugarcane harvesting producing harmful emissions. In India, if all the cane trash be utilised to full potential, the national energy deficit can be reduced by 50%. Moreover, the sugar industry gets an additional 110% power export in the process. Unfortunately, the collection mechanisms in vogue are uneconomical and not suitable to realise the potential energy benefits. Deccan sugars, sugar mill of Nava Bharat Ventures Ltd has tried a collection mechanism by harvesting dry leaves along with cane and processing it through the milling tandem, thus increasing bagasse generation. Sugarcane trash has high alkali and silica content, which makes it unsuitable as boiler fuel directly. Trash processed with the cane supply is thoroughly washed in the milling process, thereby significantly reducing the alkali and silica content of the resultant bagasse. Harvesting and processing trash along with sugarcane seems to be a good method to make trash a suitable boiler fuel and realise its potential.

Introduction

The Indian Sugar Industry is progressing well in its efforts to expand the implementation of cogeneration. The industry is progressively achieving benchmarks in reduced process energy consumption. A few sugar mills have reduced steam consumption to 340 kg/tonne cane producing direct white consumption sugar by following the double sulfitation process. A few more are aiming to achieve steam consumptions of 300 kg/tonne cane.

In India, sugarcane cultivation is done manually except for the operations of land preparation and cane transportation for which tractors are used. Green cane harvesting is done manually. Green leaves and cane tops are used as fodder. Manual harvesting has become a serious production bottleneck threatening the survival of the sugar industry. Various types of mechanical harvesters are being tried in the recent past.

Sugarcane trash, the dry brown leaves attached to the cane stalk, to some extent forms mulch in the fields 5–6 months into the initial growth or ratooning period. Post harvest burning of trash is common practice, releasing harmful greenhouse gases like N₂O, CH₄ and CO₂ in addition to CO. Very few sugar mills having a cogeneration facility are trying to collect trash from the fields by using balers. Manual collection and transport of loose trash from fields is practised at certain mills.

Biomass has got a lot of potential in varied applications from power generation to plastics. There is a growing interest and need for an efficient biomass collection mechanism. Cane trash is a potential source of biomass with well established benefits as a fuel and manure. Appropriate collection mechanisms and attractive markets for trash will make sugarcane cultivation more profitable.

Deccan sugars have undertaken trials to demonstrate the efficient collection of trash by whole-of-crop harvesting and milling. This was to provide additional fuel to their 9 MW [rated

boiler pressure: 43 bar (abs)] and 20 MW [rated boiler pressure: 87 bar (abs)] capacity co-generation facilities. The associated factory process steam consumption has been reduced to 350 kg/tonne cane.

The mill is situated in coastal districts of Andhra Pradesh, South India in the tropics at 17°02'N latitude and 82°09'E longitude. Average altitude is 15 m above MSL. Cyclonic conditions prevail in the area during the cane growing period. Soil conditions and a cyclonic climate are the cause of severe sugarcane lodging. Land holdings are small averaging 1.1 ha. Many fields are not easily accessible for sugarcane transportation. Harvested sugarcane is shifted manually by laborers to a convenient place for loading.

The mill has the capacity to crush 450 000–585 000 tonnes of sugarcane annually. In the recent past, due to uneconomical margins for sugarcane farming with increased labour costs, the crop production reduced to 240 000 tonnes. As the crush rate reduced, we were able to trial this unique approach to trash collection.

Cane trash handling and utilisation—previous research and experiences

Sugarcane produces huge quantities of foliage; up to 40% of total biomass. On an average, 15–20 tonnes of cane trash are produced per hectare. However, the quantity varies with varieties and crop growth. Cane trash contains considerable amounts of plant nutrients. These nutrients can be conserved if recycled into the soil. However, the entire amount of trash obtained from cane fields cannot be utilised for mulching, as an excessively thick blanket of mulched trash can inhibit germination, harbors reptiles and results in poor cane growth.

Results obtained at the Regional Agriculture Research Station, Anakapalle, India led to the recommendation of 3 t/ha of trash mulching to conserve soil moisture and nutrients (Ramalingaswamy 1998). However, mulching is more effective in upland and light soil conditions. The 12 to 17 t/ha of surplus trash has to be economically utilised by proper collection.

Post-harvest trash burning causes loss of nutrients (Krishna, 2002). Cane stubbles get damaged due to the heat and cause delayed germination resulting in poor yield during ratooning. Burning trash generates intense heat ranging from 600°C to 800°C which kills beneficial soil microorganisms and earth worms. The global warming potential of gases such as N₂O and CH₄ in addition to CO₂ that are released during burning is of greater concern. N₂O is the most worrying emission because of its high global warming potential (300 times more damaging than CO₂).

Sugarcane has significant potential as a source of biomass fuel. Sucrose in the stalk only represents approximately 30% of the total energy of the above ground biomass of sugarcane. C4 species like sugarcane will outperform C3 species in their ability to accumulate biomass. The maximum above ground biomass growth can be as high as 550 kg/ha/day. When grown under rain-fed conditions, sugarcane has one of the highest water use efficiencies of all crops in terms of water used per unit mass of biomass produced (Botha, 2009).

Energy potential in cane trash

Sugarcane is an energy crop produces the energy equivalent per hectare per cropping cycle of 95–114 barrels of crude oil (Botha, 2009; Ripoli, 2000; Rein, 2007; Krishna, 2002). 60% of the energy is transported to the mill as clean cane, 12% is utilised as fodder (young internodes and green leaves) and the rest 28% (trash) is predominantly burnt in the open (Ripoli, 2000; Rein, 2007; Krishna, 2002).

Cane trash is a potential fuel with a calorific value ranging from 3845–4375 kcal/kg on dry basis (Kurt woytuik, 2006) having moisture in the range of 20–30%.

With an average yield of clean cane of 75–80 t/ha, each hectare of sugarcane cultivation has 12–17 tonnes of excess cane trash available. This is equivalent to a primary energy value of up to 50 000 kWh per hectare of sugarcane-cultivated land. However, associated activities in the process of generating energy from trash such as transportation, processing and energy extraction influence the actual electrical energy benefits reaped from cane trash.

Cane trash as fuel for power generation—the challenges

Field level challenges

Pricing mechanism—Farmer confidence

For a long time now, farmers have been accustomed to send fresh clean cane to the mill. Payment is made to farmers on a weight basis. Average recovery from the previous campaign is also considered in the payment system.

A suitable pricing mechanism for the whole-of-crop harvested cane has to be developed to provide sufficient confidence in farmers.

Collection and transport

Low bulk density

Low bulk density accounts for higher transportation and handling costs. Trash has a very low bulk density, which invariably increases the collection and transportation cost. Experiments at the mill have shown that the density of loose trash is in the range of 50–65 kg/m³. Cane stalk bundled with dry leaves is found to have a bulk density in the range of 220–230 kg/m³.

Baling is one alternative for reducing trash collection and transportation costs. Trash can be compacted to 242–306 kg/m³ using large rectangular balers (Hassuani *et al.*, 2005). However, baling is energy intensive compared to trash collection along with cane.

Collection efficiency

It is observed that 56–84% of trash can be collected by raking and baling trash (Hassuani *et al.*, 2005). We can achieve more than 95% trash recovery by harvesting trash along with cane.

Soil % in trash

The collection mechanism must also ensure that soil is not entrained with the trash during collection. Baling without a prior raking operation is found to have a soil content in the range of 5–6%. With the raking operation, the sand content in the bales is in the range of 1.5–2.0%. (Hassuani *et al.*, 2005).

The soil cannot be easily separated and hence results in excessive erosion in boilers whereas, in the case of harvesting trash along with lodged cane, there is a possibility to provide a sand separation mechanism before processing it in the mill.

Factory level challenges

Fuel usage challenges

Total alkali, sulfates, chlorine and silica concentrations in trash

Alkali metals in conjunction with other inorganic components such as silica, sulfur and chlorine are primarily responsible for slagging and fouling, which reduce the boiler efficiency. These components are common in herbaceous crops. They play an important role in the plant metabolism (Kurt woytuik, 2006).

Volatile alkali metals at high temperatures form inorganic gases which react with other fuel components to exacerbate ash deposition problems by two primary mechanisms. The first mechanism is by reduction of the ash fusion temperature due to the formation of alkali silicates. The second mechanism is by condensation of alkali vapours on boiler tube surfaces, which react with sulfur to form alkali sulfates reducing the boiler effectiveness (Baxter and Jenkins, 1995). Chlorine assists in effective transport of alkali vapours to the boiler tube surfaces (Miles, 1995).

The tendency to form deposits or slag increases significantly at ash levels of between 0.17 kg/GJ to 0.34 kg/GJ. Fouling and possible slagging occurs above those total alkali concentration levels (Miles, 1995).

The total alkali concentration of the fuel can be reduced by blending with a processed fuel-like bagasse. However, composite data (calculated from analysis reports of raw cane trash and bagasse) presented in Figure 1 show that the total alkali, Cl and SO₃ concentration per unit energy is

still above the threshold level (0.17 kg/GJ) for fuel mixtures having trash contents greater than 20%. Boiler manufactures are recommending trash to bagasse ratio of 10:90 for the latest high pressure boilers.

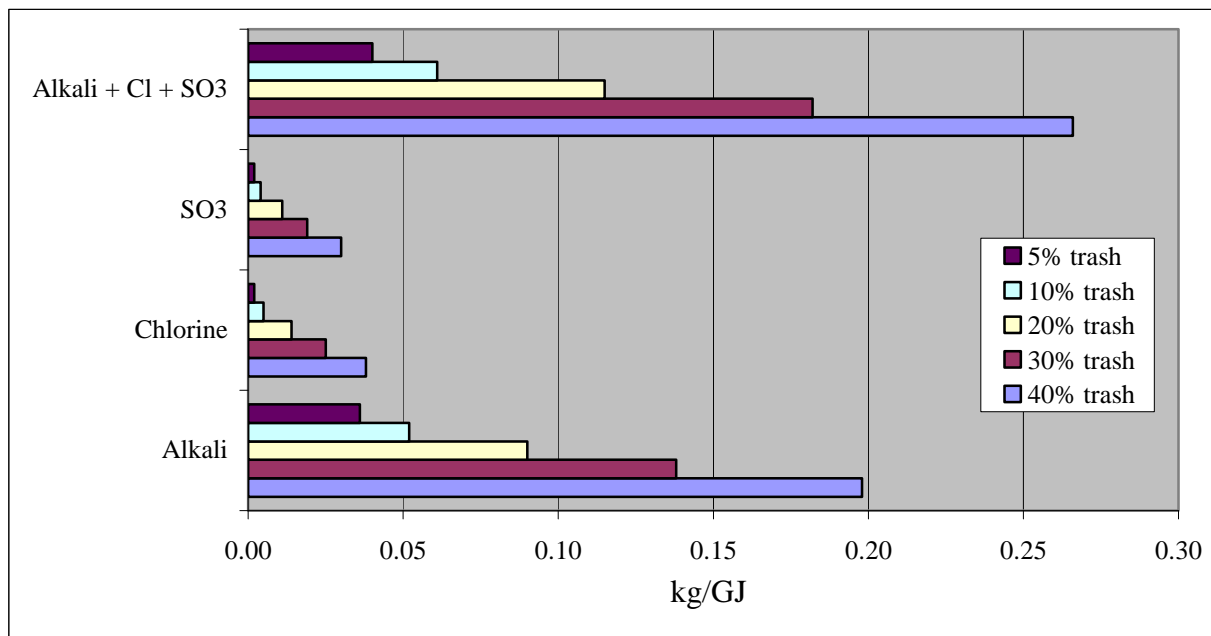


Fig. 1—Alkali content in trash-bagasse fuel mixture per unit energy content at different mixture concentrations.

Pilot scale experiments on a Cuba mill in Hawaii have shown that leaching by milling is very effective in reducing the total alkali, sulfur and chlorine content of trash. It is also observed that considerable improvement in leaching was achieved by decreasing the particle size (Kurtwoytk, 2006).

All herbaceous crops have higher concentrations of the alkali metals, chlorine, silica and sulfates. Leaching is already proven to improve fuel characteristics in the case of bagasse. Bagasse generated by milling trash along with cane is having the total alkali index well below the threshold 0.17 kg/GJ level because of the efficient leaching in milling.

Trash processing challenges

Crushing rate

The cane crushing rate is found to reduce by 2.3% for 1% increase in trash % cane processed in milling tandems, primarily due to increased fibre content. It is found that the fibre rate is not affected by processing additional trash along with cane (Kent, 2007).

Energy consumption

Electrical energy consumption at the milling station will theoretically increase due to the additional fibre content in trash. However, the lignin content, which generally provides the rigidity or hardness in fibre, is comparatively less in fibre of trash. Hence, the power consumption per tonne of fibre in trash will be less than that of fibre in cane stalk. There will also be an increase in steam consumption due to increased mixed juice % cane.

Juice quality and sugar extraction

It is observed that increase in trash processed along with cane during milling results in reduction in purity of juice, increased extraction of reducing sugars and loss of pol carried through extra fibre in trash. A 0.1 unit decrease in extraction and 0.3 units decrease in mixed juice purity was observed for 1% increase in trash % cane. (Kent, 2007)

In the current study, it is assumed that the effect of the above challenges for processing trash in a milling tandem can be managed within limits through minor changes to milling and sugar processing plants.

Methodology

Three trials of 440 minutes duration were undertaken by the mill to evaluate the potential and actual effects on the entire mill of using cane trash as fuel in the existing infrastructure. During the three trials, 89 tonnes of trash were processed along with 417 tonnes of clean cane. The cane received along with trash at the mill was fed to the cane carriers using grab unloaders and processed through three sets of knives, a cane shredder and a 4 milling tandem of 30 × 60' size with underfeed rollers. The last mill is equipped with a grooved roller pressure feeding device.

The increased bagasse due to extra fibre content in trash is used as fuel for the cogeneration system. The cogeneration system constitutes a 64 t/h travelling grate boiler generating superheated steam at 43 bar (abs) and 415°C. In the campaign, 3000 tonnes of trash were processed intermittently but at regular intervals with cane in the mill.

Results and discussion

Harvesting and transport of trash along with cane

The work required for detraging during harvesting has reduced but head load to be carried to the truck per hectare has increased. The cost of transportation has also increased due to reduced bulk density of trash along with cane in comparison with clean cane. During the trials, cane trash levels of around 21.4% of the total clean cane received at the sugar mill were recorded. The cane trash levels recorded during the trials are given in Figure 2.

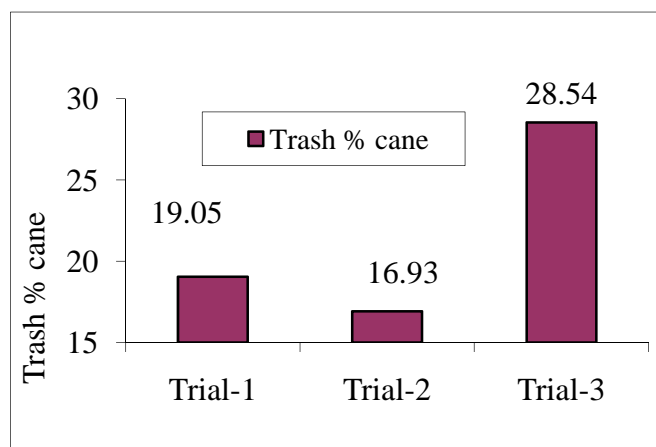


Fig. 2—Cane trash processed during trials as percent of clean cane.

Processing trash along with cane through mills

An effective analysis system is essential to arrive at an accurate price for sugarcane which is consistent with the existing cane payment framework. It is essential for the analysis system to provide sufficient confidence for farmers to participate in the harvesting of trash with cane.

Unfortunately, core samplers and NIR analysers are not currently used as the basis for determining the sugarcane price. We had to adopt a random sampling and weight-based analysis system. We have demonstrated its working to the farmers for encouraging harvesting trash along with cane.

The fibre rate through the milling plant has decreased by 14.28% because of inadequate feeding facilities suitable for milling trash along with cane.

Imbibition

To maintain effective sucrose extraction, imbibition was increased to compensate for the increase in fibre content. Pol % bagasse remained at 1.8% for increase in imbibition % cane in the

range of 1.7–1.25 units for 1% increase in trash % cane. The pol in bagasse increased rapidly by further decreasing the increment in imbibition % cane (Table 1)

Table 1—Percentage increase in Imbibition % cane for 1% increase in trash % cane.

Trial no.	Increase in imbibitions per unit increase in trash % cane	Pol % bagasse
Trial-1	1.781	1.8
Trial-2	1.280	1.8
Trial-3	0.762	2.01

Extracted juice properties

Sucrose extraction in mixed juice

Table 2—Mixed juice quantity (MJ) and % pol observed during trials.

Trial no.	Normal values without trash		Values during the trials	
	Pol % MJ	MJ % cane	Pol % MJ	MJ % cane
Trial-1	10.53	108.65	7.21	149.86
Trial-2			8.1	133.78
Trial-3			7.42	146.20

Table 3—Decrease in sucrose extraction for 1% increase in trash % cane*.

Trial no.	Decrease in sucrose extraction (kg / tonne cane)	Trash % clean cane
Trial-1	0.33	19.05
Trial-2	0.36	16.93
Trial-3	0.21	28.54

*derived from data in Table 2

Table 3 shows the effect on sucrose extraction of processing trash along with cane. As it is observed, there is a 0.21–0.36 kg per tonne cane decrease in sucrose extraction for 1% increase in trash % cane. Because of the relatively short nature of the trials, it was not possible to directly measure the effect of trash on sugar quality and recovery. However, the decrease in sucrose content mixed juice (Table 2) is a clear indicator of the effect on sugar recovery.

Colour removal

Table 4—Value of IU measurements made during trials.

Trial no.	Mixed juice colour (normal value without trash)	Mixed juice colour during trials
Trial-1	19 146	46 000
Trial-2		32 669
Trial-3		35 403

Table 5—Colour removal during clarification process.

Normal values without trash			Values during the trials		
Mixed juice colour	Clear juice colour	Colour removal %	Mixed juice colour	Clear juice colour	Colour removal %
19 146	17 783	7.12	35 403	23 524	33.55

From Table 4 above, there is considerable increase in mixed juice colour observed by processing trash along with cane during the trials. Starch content in the leaves is believed to be primarily responsible for the increased juice colour. There is an increase of between 550–1400 IU colour units in mixed juice for a 1% increase in trash % cane. However, as per Table 5, considerable removal of juice colour was observed in the juice clarification process. The residual colour in clear juice is easily removed in syrup clarification and crystallisation processes. Hence, trash was deemed to have no significant impact on the sugar colour of the product (Figure 3).

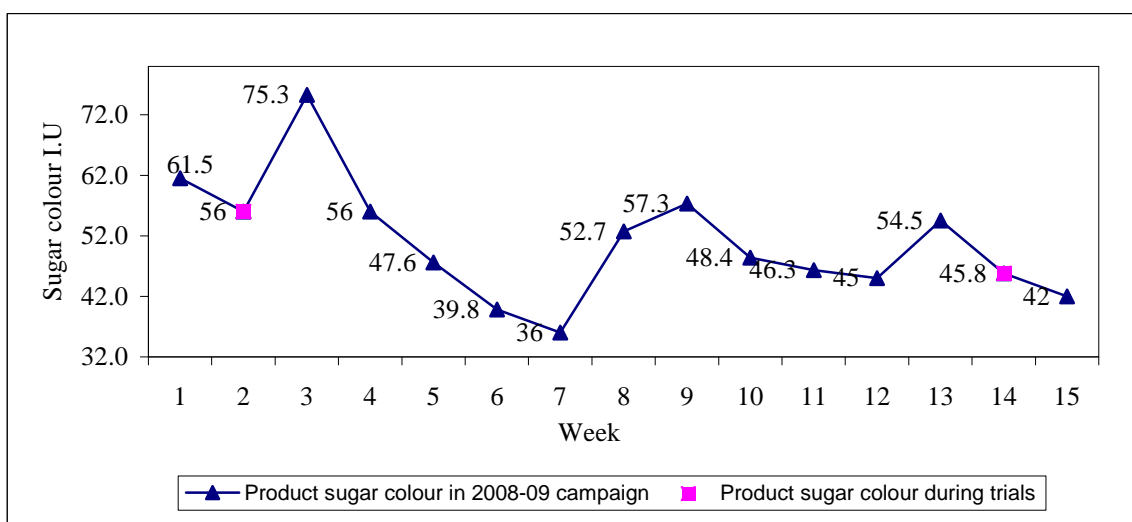


Fig. 3—Product sugar colour in 2008–09 campaign starting from 24 November 2008.

Boiler performance

Leaching of trash during milling ensured a clean fuel for the boiler. The analysis of the fuel showed concentration of alkali in ash well below the threshold level responsible for slagging. Figure 4 shows a comparison of measurements of concentrations of alkali Cl^+ and SO_3^+ ions in bagasse from clean cane, from trash processed along with cane, and with that of trash in its naturally occurring state.

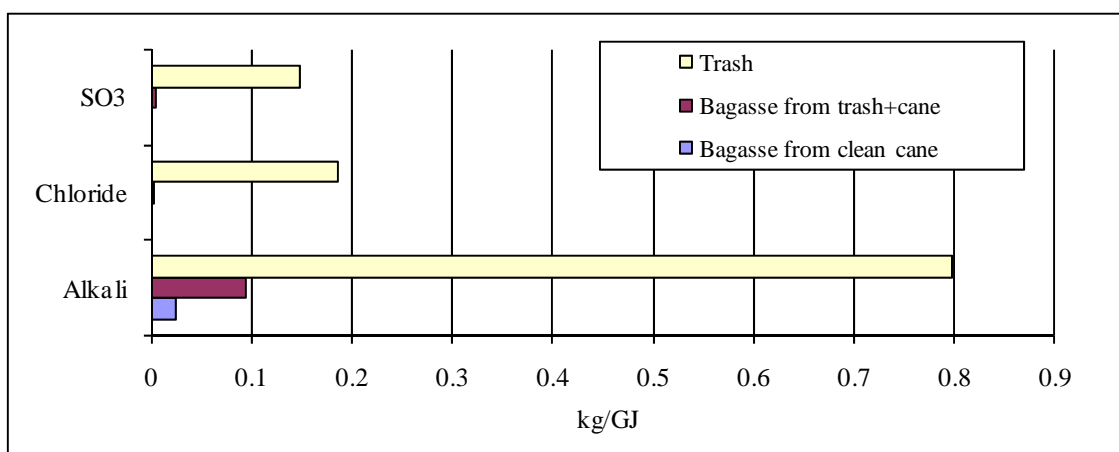


Fig. 4—Alkali, chlorine and SO_3 concentrations per unit energy (kg/GJ).

The results have clearly shown that leaching effectively removes alkali content from trash. There was no noticeable change in the performance of the boiler vis-à-vis flue gas temperature profile as shown in Figure 5.

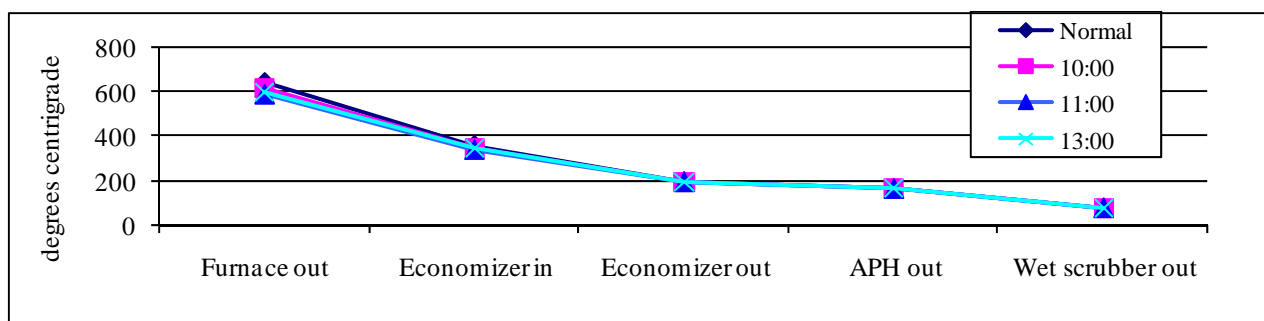


Fig. 5—Effect of using leached cane trash along with bagasse as fuel on the boiler flue gas temperature profile.

Increased sand content in bed ash is observed, indicating excess silica being entrained with the trash during trials. Installation of sand separators at the mill feeding point would reduce the excess sand content in cane with trash.

There was an increase in the oxygen content in flue gas during the trials (Figure 6) which may presumably be due to increased moisture content to 52% or the changed fuel properties.

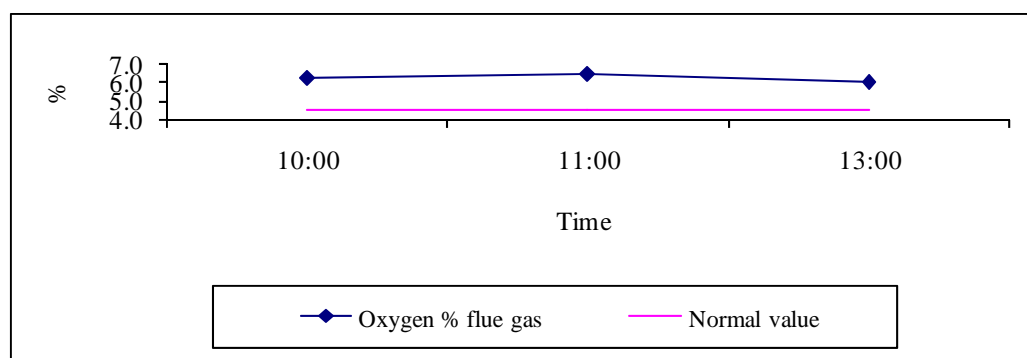


Fig. 6—Oxygen content in flue gas during Trial 3.

Cost of trash

To understand the economics of collection and harvesting trash as a fuel, a value for trash has been derived by assigning costs to various activities and effects involved (Table 6).

Table 6—Incremental cost of trash as fuel by processing it along with cane in the milling tandem.

S. no	Description	Value (US\$/tonne of trash)
1	Trash price paid to farmer	4.0
2	Transport charges	5.0
3	Power consumption for leaching trash (90 kWh / tonne fibre and \$80 / MWh)	5.0
4	Steam consumption due to increased imbibition (0.02 t bagasse @ \$30 per tonne bagasse)	0.6
5	Sugar loss through bagasse (Assumed sugar price of \$460/tonne)	13.0
6	Sugar loss through molasses (Assumed sugar price of \$460/tonne)	7.0
7	Realization from 1% on cane increased molasses @ \$120/t molasses (due to increment in juice RS content)	- 6.0
8	Cost of trash	28.6

Hence, a valuable fuel is available to the mill at \$28.6 / tonne or \$1.66 / GJ. Hence, processed trash is far more attractive than crude oil [\$8.7 / GJ] or coal with carbon capture [\$4.8/GJ] (Botha, 2009).

Conclusion

In a country like India, a farmer is used to delivering clean cane to the mill and receiving payment on the basis of weight and previous campaign mill average recovery. The impact for an Indian scenario of collecting and milling trash along with cane has been undertaken. Apprehensions associated with factors such as deterioration in sugar quality, clinker formation and fouling in boiler and resistance from farming community for such change in harvesting and transportation can be overcome to some extent by these successful trials.

These preliminary trials have yielded interesting results such as:

1. The dried leaves, non cane portion for milling worked out to be approximately 20% of clean cane on weight basis.
2. Raw cane trash (i.e. prior to milling) has a higher calorific value in the range of 3845–4375 kcal/kg on dry basis.
3. Leaching trash in mills effectively reduced fuel alkali concentration delivering a processed fuel to the boiler with minimal risk of slagging.
4. Though transport of cane along with trash from cane fields to sugar mill involved greater transportation costs, trash contributed considerably to the increase in quantity of fuel increasing the net power export from the cogeneration plant.
5. There is a significant reduction in crushing capacity which can be moderately increased by uniform feeding.
6. The colour content of the mixed juice increased due to compounds extracted from the trash by the milling process. However, the increased colour content of mixed juice did not ultimately affect the quality of product sugar as the colour was removed in the juice clarification, syrup clarification and crystallisation processes.

Through the experience gained in this study, it has been established that the following criteria for selecting fields suitable for harvesting trash along with cane make the activity more attractive

- Trash collection should be from fields within 15 km distance from mill
- Erect (non lodging) cane varieties should be selected
- High biomass yielding cane varieties should be selected

Effective separation of sand, uniform feeding of raw material to milling tandem, evolution of right payment mechanism for dry trash based on either core sampler or NIR technique are essential in future to continue this activity.

Summarising, crushing of cane along with trash appears to be of extreme use for increased cogeneration of power. Crushing of cane along with trash reduces atmospheric pollution and helps in reducing global warming. However, the reduction in crushing capacity can adversely affect the mill operations when there is sufficient cane available to be crushed. Suitable additional milling capacity to process trash along with cane is inevitable.

These remarkable advantages of crushing cane along with trash warrant further detailed studies to help alleviate power shortages in India and reduce global warming.

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PAILLE DE CANNE COMME CARBURANT

Par

N.PRABHAKAR, D.V.L.N.RAJU et R.VIDYA SAGAR

Navoi Bharat Ventures Ltd, Samalkot, Inde.np@nbv.in

**MOTS CLEFS: Paille de Canne, Énergie,
Traitement de la Paille, Lixiviation.**

Résumé

LA PAILLE de canne, un résidu dans les champs de canne à sucre, a un potentiel important comme un carburant de la biomasse. Elle contient près de 28% de la teneur totale d'énergie dans la culture de la canne. Toutefois, ce combustible potentiel est gaspillé par le feu en plein champ après la récolte, produisant des émissions nocives. En Inde, si toute la paille de canne est utilisée, le déficit énergétique national peut être réduit de 50%; en outre, l'industrie sucrière obtient une exportation d'énergie de 110%. Malheureusement, les mécanismes pour récolter la paille ne sont pas

économiques et on n'obtient pas les avantages possibles. La sucrière de Navoi Bharat Ventures Ltd (Deccan) a essayé de récolter la paille avec la canne et de traiter le tout aux moulins, augmentant ainsi la génération de bagasse. La paille contient beaucoup d'alcalins et de silice, ce qui ne convient pas aux chaudières. La paille a été soigneusement lavée aux moulins, réduisant ainsi les alcalins et la silice dans la bagasse. La récolte et le traitement de la paille avec la canne semblent être une bonne méthode pour transformer la paille en un combustible de chaudière approprié, ce qui réalise son potentiel.

RESIDUO AGRICOLA DE LA CAÑA COMO COMBUSTIBLE

Por

N. PRABHAKAR, D.V.L.N. RAJU and R. VIDYA SAGAR

Nava Bharat Ventures Ltd, Samalkot, India
np@nbv.in

**PALABRAS CLAVE: Residuos, Energía,
Procesamiento de Residuos.**

Resumen

EL RESIDUO de cosecha de caña seco dejado en el campo tiene un potencial significativo como biomasa combustible. Contiene cerca del 28% del total de la energía de la caña. Sin embargo este potencial es desperdiciado por las quemadas abiertas en campo después de la cosecha produciendo emisiones nocivas. En India, si todos los residuos se utilizan en todo su potencial, el déficit nacional de energía puede reducirse en un 50%. Adicionalmente la industria azucarera obtiene una exportación adicional de energía eléctrica del 110%. Desafortunadamente los mecanismos de recolección disponibles no son económicos y no permiten el logro de los beneficios potenciales. Deccan Sugars, ingenio de Nava Bharat Ventures Ltd ha ensayado diferentes alternativas para la recolección de hojas secas para molerlas en el tándem, incrementando la producción de bagazo. Los residuos tienen altos contenidos de álcalis y sílice lo que los hace no aptos para uso directo en las calderas. Al procesarlos con la caña son totalmente lavados en el proceso de molienda reduciendo los contenidos de álcalis y sílice del bagazo resultante. Cosechar y procesar los residuos con la caña parece ser un buen método para convertir los residuos en un combustible adecuado para las calderas y aprovechar su potencial.