SUGARCANE TRASH RECOVERY ALTERNATIVES FOR POWER GENERATION

By

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Abstract

Several sugar/ethanol mills in Brazil are considering collecting the sugarcane trash left in the field after unburned cane harvesting. Some have already started to recover the trash and use it as a supplementary fuel to bagasse for power generation. The main purpose of such biomass recovery was to sell more power to the grid, making the sugarcane industry more profitable. Problems such as reduction in sugarcane yield and pests, in many sugarcane fields harvested unburned, are nowadays increasing the motivation towards trash recovery. Research has been carried out by the Copersucar Technology Center (CTC) with different recovery systems, such as baling, hay harvesters, trash and sugarcane harvested together and trash collected straight from the sugarcane harvester. Equipment is under development, and trials are being carried out to verify operational restrictions of trash recovery alternatives, characteristics of the biomass delivered at the mill, and cost estimates.

Introduction

Sugar/ethanol mills in Brazil have reached self-sufficiency in terms of energy consumption in the past decades. Adoption of adequate operating conditions of the plant, in terms of boiler pressure/temperature (22 bar, 300°C), process steam consumption for thermal energy (330 kWh/t of cane or 500 kg steam/t of cane @ 2.5 bar) and mechanical-electric energy (30 kWh/t of cane) to operate the factory during the crushing season, led to a balance situation where the bagasse generated during cane crushing and used as fuel in the system is just enough (excess bagasse around 5%).

Changes in regulations and privatisation of the power sector established favourable conditions to generate and sell electricity. Several mills in Brazil are already selling electricity to the grid during the harvesting season (six to seven months), with a few generating electricity year round. Investments in new boilers (up to 82 bar, 480°C) and reduction in steam process consumption (down to 340 kg/t of cane) were carried out in some cases.

Year-round power generation required supplemental fuel to bagasse. The introduction of unburned cane harvesting, increasingly adopted in most regions of southeast Brazil due to environmental laws, produced a large amount of residues (tops, dry and green leaves) left in the field. This harvesting residue or trash is the alternative under consideration, and is already being employed on a small scale by some mills as the supplementary fuel to bagasse.

For many years, Copersucar has been investigating the recovery and use of sugarcane trash as the supplemental fuel to increase the power generating capacity of mills in several studies including Project BRA/96/G31, a share funding project with the Global Environment Facility (GEF).

Although the aims of this project were toward the advanced technology of Biomass Integrated Gasification/Gas Turbine (BIG/GT), the knowledge acquired for trash availability, quality, recovery and handling and the associated environmental impacts can be directly used to implement projects of conventional cogeneration systems in the mills. The size of the cogeneration plant will depend among other factors on the amount of recoverable trash. Field experiments executed, taking into consideration cane variety, age, and soil, estimated the average amount of trash in the field per metric tonne of cane stalk as 140 kg of dry matter, comparable to the average of 280 kg of bagasse/t of cane (50% moisture content). Sugarcane harvesting cleaning efficiency and trash recovery efficiency will define the amount of trash collected.
Several agronomic benefits of leaving the trash in the field (trash blanketing) have slowed down trash recovery, such as: soil protection against erosion, reduced soil temperature variations, increased biological activity and water infiltration in the soil, more water available due to the reduction in water evaporation, and control of most weed species (with reduction in herbicide use).

Nevertheless, the implementation of trash blanketing practice in larger areas has led to some drawbacks, initially not observed or considered, such as: fire hazards, difficulties in carrying out mechanical cultivation, ratoon fertilisation and weed control through the trash blanket, delayed ratooning and the occurrence of gaps (discontinuity of sprouts in the line of cane).

These factors cause a reduction in cane yield when temperatures are low and/or the soil is very wet and, especially, an increase in population of pests that shelter and multiply under the trash blanket.

The high intensity of such problems in some areas is driving some mills to consider removing all the trash. Using trash as fuel for energy generation is becoming, in such cases, a way of reducing agronomic costs. Trash recovery results for some of the alternatives tested is summarised and the technology under development is described.

**Baling**

During unburned mechanised cane harvesting, cane is chopped in pieces and blown in the harvester to remove the trash that is left in the field, with the cane loaded to infield equipment or trucks. The amount of trash that is taken with the cane is a function of the cleaning efficiency of the harvester (adjusted to acceptable cane loss). On average, 80% of the trash is blown out of the harvester and stays on the ground, and 20% is taken to the mill together with the cane as extraneous matter.

Trash, similarly to other forms of biomass, is found in very low-density forms resulting in high recovery and transport costs. Baling is an alternative for trash recovery, with increase in density and transformation of the biomass in uniform units (bales) leading to a reduction in residue collection and transportation costs. Several machines have been tested with small and large round bales and small square bales (Table 1).

The results indicated that small rectangular balers have higher productivity, better ability to deal with trash and pieces of cane left in the field, and better space utilisation by the bales in the transportation truck. However, the difficulty in recovering large numbers of small rectangular bales from the field, and their stacking in the truck, indicated that large rectangular bales should be used.

<table>
<thead>
<tr>
<th>Type of bale</th>
<th>Small round</th>
<th>Large round</th>
<th>Small rectangular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baling system</td>
<td>Fixed drums</td>
<td>Belts</td>
<td>Press</td>
</tr>
<tr>
<td>Baler operational capacity (t/ha)</td>
<td>1.8</td>
<td>2.7</td>
<td>9.0 (3)</td>
</tr>
<tr>
<td>Bale weight (kg)</td>
<td>106</td>
<td>286</td>
<td>15</td>
</tr>
<tr>
<td>Bale bulk density (kg/m^3)</td>
<td>118</td>
<td>95</td>
<td>112</td>
</tr>
<tr>
<td>Soil in the bale (%)</td>
<td>5.6</td>
<td>6.2</td>
<td>Na</td>
</tr>
<tr>
<td>Trash recovery efficiency (%)</td>
<td>62</td>
<td>52</td>
<td>Na</td>
</tr>
</tbody>
</table>

Tests using large rectangular baler Case 8575 carried out at Usina São Luiz AA – Pirassununga – State of São Paulo (Figure 1) considered 1 x 1 raking (after cane harvesting, trash in the area between two lines of cane is raked over the adjacent area), 2 x 1 raking (over the area between two lines of cane, trash is raked from the two adjacent areas) and no raking.

Despite good baler results in the no raking test (Table 2), conducted in a smooth experimental area, raking is almost a must due to usual field irregularities, with raking 2 x 1 having the best performance. Bales were collected and loaded on transport trucks using a sugarcane grab loader.

Baling operations took place usually a week after harvesting, allowing trash to dry to a moisture content below 20%, being preceded by trash raking. Raking operation is very important to improve baler performance and to reduce damage to the pick up system that can work without direct earth contact, reducing baler maintenance and soil in the bale.

395
Table 2—Summary of baling tests results.

<table>
<thead>
<tr>
<th>Bale parameters</th>
<th>Raking 1 x 1</th>
<th>Raking 2 x 1</th>
<th>No raking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (m)</td>
<td>0.80 x 0.87 x 1.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average weight (kg)</td>
<td>242</td>
<td>306</td>
<td>295</td>
</tr>
<tr>
<td>Bulk density (kg/m³)</td>
<td>183</td>
<td>231</td>
<td>223</td>
</tr>
<tr>
<td>Average moisture content (%)</td>
<td>12.0</td>
<td>15.3</td>
<td>13.1</td>
</tr>
<tr>
<td>Soil (%)</td>
<td>3.5</td>
<td>4.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Dry trash (kg)</td>
<td>185</td>
<td>216</td>
<td>231</td>
</tr>
<tr>
<td>Dry density (kg/m³)</td>
<td>140</td>
<td>163</td>
<td>175</td>
</tr>
<tr>
<td>Baling operational parameters of dry clean trash</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baling trash + manoeuvres (t/h)</td>
<td>6.5</td>
<td>9.1</td>
<td>9.8</td>
</tr>
<tr>
<td>Diesel consumption (L/t of dry clean trash)</td>
<td>2.0</td>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Recovery efficiency (%) (4)</td>
<td>56</td>
<td>84</td>
<td>73</td>
</tr>
</tbody>
</table>

1) Bulk density: it is the apparent density of the bale, calculated by the ratio: 
   \[
   \text{Average weight/volume of the bale.}
   \]

2) Dry trash: it is the mass of dry clean trash in a bale calculated by the equation:
   \[
   \text{Average weight.}(1 - (\text{Soil + Cane}/100))(1 - \text{Humidity}/100).
   \]

3) Dry density: it is the apparent density of the bale, considering the volume of the bale and
   the mass of dry clean trash. It is calculated by the ratio: 
   \[
   \text{Dry trash/volume of bale.}
   \]

4) Recovery efficiency: indicates the percentage of trash recovered in relation to available
   trash in the field after green cane harvesting and before baling.

An estimated amount of 67% of the initial trash can be baled (Figure 2), considering trash recovery
with large square balers in areas harvested unburned and raked 2 x 1, with a baler recovery efficiency of
84%.

During baling tests, several problems were observed, related to the baler equipment, suggesting
that improvements should be made, or related to the concept of collecting the trash from the ground, such as:

- Need for longer drying periods if it rains on the trash.
- Time limitations after harvesting due to cane growth and tillage operations.
- Soil that is added to the trash during the raking operation and trash recovery.
- Chocking problems in the baler recovery system due to the presence of cane left in the
  field.
- Premature components wear and bale plugging inside the baler due to high moisture
  content and soil in the trash.
- Lack of reliability of the balers, specially of the twine tying system.
- Need for twine removal and shredding of the bales at the mill if they are to be burnt in
  conventional furnaces or used in BIG-GT systems.
Hassuani, S.J. et al.  

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Sugar cane field  
Initial trash % of stalks = 14%

Harvesting operation  
Cleaning efficiency % = 80%

Trash left in the field  
Trash % of initial trash = 80%

Trash recovered from the field  
Recovery efficiency = 84%

Trash left in the field after bale recovery  
Trash % of initial trash = 13%

Cane with trash transported to the mill  
Trash % of initial trash = 20%

Baled trash transported to the mill  
Trash % of initial trash = 67%

Total trash at the mill  
Trash % of initial trash = 87%

Fig. 2—Conventional unburned chopped cane harvesting with trash baling.

A total cost of US$9.60 per tonne of baled trash (clean and dry matter) delivered at the mill was estimated at the time of the experiments, considering raking, big square bales baling, bale collecting, transport and unloading at the mill site.

It is important to use adequate equipment for bale collection from the field, loading, transport and unloading. Studies of the layout of the bales in the transportation truck body should be carried out to determine truck and bale length to optimise the transported volume and reduce the number of bales. Due to low bale density, transport trucks should tow the maximum number of trailers allowed by law to maximise transport load.

It has been observed that mills that are recovering trash through baling are usually employing round fixed drum balers (with fixed bale chambers) due to the availability of such equipment in the country, simpler maintenance, and low cost of the machines. Large rectangular balers are high cost and heavy, and usually not available for immediate purchase.

Hay harvesters

An alternative to balers for trash recovery is a hay harvester. Following a raking operation, trash is collected and shredded by the hay harvester, which transfers the processed material to a transport truck. At the mill site, trucks are unloaded using front loaders (Figure 3).

Fig. 3—Hay harvester recovering trash and truck unloading.
Tests with Claas 880 and John Deere 6850 machines conducted at Usina da Barra – Barra Bonita – State of São Paulo resulted in an average recovery efficiency of 66%, with soil content of 10% in the collected trash. The total collected trash corresponds to approximately 53% of the initial trash available in the sugarcane field (Figure 4). To attempt to reduce soil content in the recovered trash by lifting the machine recovery system reduced the recovery efficiency to 50% with a soil content of 7%.

Average operational capacity of 12.6 t/h of recovered shredded trash (dry matter) was obtained in the tests, considering only operating time plus manoeuvres, with average diesel fuel consumption of 31 L/h. Most trucks transported an average load of 6 tonnes of shredded trash, with calculated values of 96 kg/m³ for bulk density of the loaded trash (including mineral impurities), with an average moisture content of 15%.

Total cost including raking, trash recovery, transport, and unloading operations was estimated to be US$13.20 at the time of the experiments, considering dry matter with no mineral impurity. It is important to point out that there are many factors that can affect this cost, such as soil characteristics (that impact on the life of shredding knives) and number and size of trailers with the truck (that impact on transport cost).

Some mills that started to use hay harvesters as a means to recover trash faced several problems that resulted in higher costs than initially estimated. There are many improvements to be made in the machine and in the system itself, such as reduction in the amount of soil collected with the trash, improvements to the life of the shredding knives, transport cost reduction, as well as the purchase cost of the equipment. The machines were not designed to work in this particular field condition, resulting in increasing down time from one season to another.

![Diagram](image)

**Fig. 4—Conventional unburned chopped cane harvesting with trash recovery with hay harvesters.**

Nevertheless, an important advantage of this system is to deliver trash to the mill in fineness adequate to be fed and burned in boiler furnaces or gasifiers, with no investment at the mill site except for simple equipment to mix the bagasse with trash. This makes it possible for a mill to start using trash on a small scale until there is confidence, reliability and cost benefit with the operation.

**Trash and sugarcane harvested together**

This trash recovery alternative considers chopped sugarcane harvesting of unburned fields, without cane trash removal at the harvester and trash separation from the cane at the mill with a Dry Cleaning Station. Harvester primary and secondary extractor fans are turned off to collect all the material (cane and trash) and bring it to the mill. Cane topping is maintained in order to leave the green leaves in the field to
guarantee a minimum protection of the soil surface. Bringing green leaves to the mill has the disadvantage that they are more difficult to separate from the cane and have lower calorific value due to high moisture content.

Tests conducted by Copersucar in different projects, including the GEF Project, allowed comparisons between conventional harvesting and no trash removal harvesting. Conventional harvest cleaning efficiency of 80% changes to 24% for no trash removal harvesting (this efficiency of no trash removal harvesting is due basically to the tops that are left in the field). As expected, there is a large increase in vegetal impurities in the load, and also a considerable increase in soil impurities (Table 3).

Table 3—No trash removal harvesting field trial summary results.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conventional harvesting</th>
<th>No trash removal harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvester vegetal impurities cleaning efficiency (%)</td>
<td>81</td>
<td>24</td>
</tr>
<tr>
<td>Soil in harvested load (%)</td>
<td>0.85</td>
<td>2.0</td>
</tr>
<tr>
<td>Vegetal impurities (dry matter) in the load (%)</td>
<td>2.3</td>
<td>12</td>
</tr>
<tr>
<td>Cane losses related to clean harvested stalks (%)</td>
<td>6.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Average truck trailer load (t)</td>
<td>20.6</td>
<td>10.6</td>
</tr>
</tbody>
</table>

No trash removal forces the harvester to operate at a lower speed than conventional harvesting but, as the amount of material also increases, there is not much difference in harvesting operational capacity (cane and trash). For the no trash removal alternative, great impact occurs in transport operation, where the great amount of trash reduces the load of the trucks by half.

Field operations do not require different equipment than those already used in conventional harvesting. The difference is merely operational, and does not require the use of extra machinery to collect the trash in the field avoiding agronomic drawbacks like soil compaction.

An important benefit of no trash removal harvesting is the reduction of sugarcane losses as a result of turning off extractor fans, which are responsible for the majority of cane losses. Tests showed a loss reduction of 4.5 t/ha in an 84 t/ha yield area, when compared to conventional harvesting.

On the other hand, this alternative requires expensive industry modifications. A dry cleaning station is necessary to process the material (cane + trash) that comes from the field. At the station, cane, mineral and vegetal impurities are separated by means of a modified feeder table and a sequence of blowing chambers (Figure 5). Trial results indicate cleaning efficiency (dry matter) around 70% for mineral impurities and 60% for vegetal impurities (leaves), with separation of 46% of the initial trash (Figure 6). Both efficiencies can be increased considerably with some ongoing improvements.

It is important to mention that the existing commercial harvesters, infield side bins, and trucks were not designed for such an operation. Changes in equipment to this trash recovery concept would result in an increase in harvester capacity and in lighter transport equipment, focused much more in volume capacity than load.
Sugar cane field
Initial trash % of stalks= 14%

Harvesting operation
Cleaning efficiency % = 24%

Trash left in the field
Trash % of initial trash= 24%

Cane with trash transported to the mill
Trash % of initial trash= 76%

Trash separation from the cane at the Dry Cleaning Station at the mill
Cleaning efficiency=60%

Trash crushed with the cane
Trash % of initial trash= 30%

Trash separated from the cane
Trash % of initial trash= 46%

Total trash at the mill
Trash % of initial trash= 76%

Fig. 6—Unburned chopped cane harvested together with trash.

Trash recovery from the harvester
The Copersucar Technology Center has been developing a device¹ that will produce and collect shredded trash during the harvesting process. The task requires the development of a suitable shredder and means for delivering the shredded trash to an infield bin.

Fig. 7—Harvester primary extractor fan and two stage counter rotating set of multiple shredding blades—project and prototype.

Shredding on the harvester will eliminate the handling step of trash recovery from the ground, while finely shredded trash will pack to a higher bulk density, and feed readily into the boilers.

The trash shredder involves replacing the conventional primary extractor fan on the harvester by a new design fan and a two stage counter rotating set of multiple shredding blades (Figure 7).

¹ Patent required.
This system is designed to produce the same cleaning action as the conventional fan, but delivering shredded trash via a duct to the second bin of tractor-towed infield equipment (Figure 8), with cane collected in the front bin. Compositions with four bins can be considered for areas where manoeuvres are not a problem. Cane and trash are transferred to specific road trucks to be taken to the mill site.

![Field tests: harvester with shredder and trash transport duct. First bin loaded with cane and 2nd with trash.](image)

Other benefits are expected with this system such as: reduced soil quantities in the recovered trash; no soil compaction due to trash recovery machine traffic; cane and trash recovered at the same time, avoiding problems with rain over the trash if it is left in the field after harvesting, and time schedule for trash recovery before cane sprout and cane tillage.

Extensive testing performed during years 2002 and 2003 at Usina Santa Adélia – Jaboticabal – São Paulo State in commercial harvesting demonstrated that the shredding and collection system work as required. Shredder reduces trash particle size substantially. The reduction in particle size is important to enable trash feeding into the furnace and to increase bulk density of the transported trash. Field trial results (Table 4) have shown that, even with substantial trash particle size reduction, bulk density increased just 30% and harvester operating capacity was reduced by 18%. Vegetal cleaning efficiency was increased but with an increase in cane losses.

**Table 4—Shredded trash recovery field trial results.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conventional harvester</th>
<th>Harvester with shredder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvester capacity (operating time + manoeuvres) (t/h)</td>
<td>61</td>
<td>50</td>
</tr>
<tr>
<td>Harvester vegetal impurities cleaning efficiency (%)</td>
<td>82</td>
<td>90</td>
</tr>
<tr>
<td>Clean cane in the harvested load (%)</td>
<td>92</td>
<td>95</td>
</tr>
<tr>
<td>Clean cane harvester capacity (t/h)</td>
<td>57</td>
<td>47</td>
</tr>
<tr>
<td>Cane visible losses in the field (%)</td>
<td>1.8</td>
<td>2.5</td>
</tr>
<tr>
<td>Recovered trash bulk density (kg/m²)</td>
<td>66</td>
<td>86</td>
</tr>
</tbody>
</table>

Shredding impediment with high field humidity, rotating knives safety hazards, long-term reliability, and cost assessment are matters that should be adequately addressed before commercial release of the system.

**Conclusions**

Sugarcane trash has been under study in several countries for almost two decades now. No conclusion has been reached regarding which is the best trash recovery alternative. This happens due to the fact that several equipments used were not designed to specifically recover trash, presenting several problems and also because of the many parameters involved such as trash mineral impurities, trash moisture content, sugarcane losses, agronomic impacts, need of trash processing at the mill, equipment performance, investments needed, labour, logistics of the operation, and amount of recovered trash.
Recepción de Residuos, Generación de Energía

PALABRAS CLÉS: Cambio de Acción; Residuos

SíHASSANNN, TE.A, DA SIYÁ A. INVES

PARTE DE RECEPCIÓN DE LOS RESIDUOS DE LA COSCIA

ALTERNATIVAS DE RECEPCIÓN DE LOS RESIDUOS DE LA COSCIA

ALTERNATIVAS DE RECEPCIÓN DE LOS RESIDUOS DE LA COSCIA

¿Por qué se deben considerar estos residuos y cómo se gestionarán? La Dirección General de Producción de la Energía y Combustibles, en el marco de sus responsabilidades, ha implementado programas y políticas para el manejo sostenible de los residuos. Estos programas tienen como objetivo reducir la cantidad de residuos generados y promover el reciclaje y la recuperación de materiales valiosos. Además, se busca minimizar el impacto ambiental de los residuos a través de la implementación de prácticas y tecnologías adecuadas.

Este documento presenta diversas alternativas para la recepción y gestión de residuos en el sector de la producción de energía, con el objetivo de optimizar el uso de los recursos y minimizar el impacto negativo en el medio ambiente. Se discuten aspectos como la selección de materiales, la optimización de procesos y la implementación de prácticas sostenibles.

Recepción de Producción de la Paloma

MÓS CLÉS: Cambio de Acción; Paloma

SíHASSANNN, TE.A, DA SIYÁ A. INVES

PORE LA PRODUCCIÓN DE LA PALOMA

DIFERENTES MÉTODOS DE RECEPCIÓN DE LA PALOMA