Development of a prototype cane-trash burner

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Abstract
This study sets out to demonstrate the technical feasibility of utilizing a sugarcane-trash burner (CTB) as part of the factory (or mill) operation to burn off trash (cane leaves) from cane stalks prior to sugar extraction, while simultaneously harnessing the energy generated in the burning process. The original pilot-scale burner was tested in 2011. This demonstrated no thermal damage to the cane while the leaves were burnt off in a confined space. In order to upscale, a conceptual design of a factory-size cane burner was undertaken. A provisional patent was registered and funding was secured to build a prototype burner. The design specifications of the prototype burner are currently underway for commissioning in August-September 2016. Final testing of the burner is planned for October-November 2016. The benefits of introducing the burning of cane into the industrial process are threefold: (i) the avoidance of the air pollution that occurs when trash is burnt off cane during in-field burning prior to harvesting (which is the common practice in South Africa); (ii) the utilisation of the energy inherent in the trash biomass at a location where the infrastructure already exists to harness this energy (boilers, electricity-generating technology) and the incorporation of CTB into the normal sugar-extraction process can be retrofitted into existing infrastructure; and (iii) the avoidance of the multiple handling steps involved in separating trash from cane stalks, as the only handling step involved would be the transport of cane stalks/billets with adhering trash to the sugar factory, which would incur some additional costs in terms of lowered sugar payload as a result of the lowered bulk density of cane with adhering cane trash.

Key words
Cane trash, renewable energy, electricity, steam generation, burner

INTRODUCTION

Sugar industries are experiencing rising production costs, coupled with falling sugar prices on the world market, and competition from alternative sweeteners. These factors are a threat to the financial viability of the industry in many countries, and it is therefore imperative to maximize efficiencies (Hassuani 2015). The use of biomass (bagasse and trash) for electrical power generation in sugar mills is one way in which a biorefinery concept can be utilized to increase production efficiencies. Brazil, a country with limited oil reserves, is currently generating 4% of its electricity at sugar mills using bagasse. In addition, it has been estimated that the contribution by the sugar industry can rise to 27% if more mills install high-pressure boilers, and utilize sugarcane trash for additional energy (Leal 2015).

From Brazil the energy value of trash (Hassuani et al. 2005) indicates that approximately 140 kg of dry residue with a heating value of 17.4 MJ/ kg (dry basis) are available per tonne of harvested cane stalks. The energy value of coal, by comparison, is approximately 32 MJ/kg (Energy Numbers 2016). The total mass of this renewable source of energy is substantial in any country that produces sugar from sugarcane sufficient for its domestic consumption. For example, production of 1 Mt sugar per year would require approximately 10 Mt of cane, and the additional energy that would be available from trash (on a dry basis) is about 1.4 Mt trash with a coal equivalent energy value of 760,000 t of coal.

If trash is to be used for energy purposes, the assumption is that the technology that converts the fuel source (trash) into a useful form of energy (such as electricity) is situated at the mill. The biomass from the trash must be burned in a boiler, and the steam produced drives turbines that generate the electricity. For this to happen, the trash needs to be conveyed to the mill. There are two options (Pierossi et al. 2016): (a) transport the trash together with the stalks/billets to the mill; and (b) separate the trash in the field and collect this into bales that are then transported separately to the mill.

The main drawback for the first option is that the larger volume of material (cane stalks and billets plus trash) transported can be as much as 35% (Pierossi 2015) than if only the cane stalks or billets themselves were transported. The trash would then have to be separated from the stalks/billets at the mill.

What makes the second option unattractive is that the process of collecting and transporting the trash requires several steps, each with its own machinery. The steps involved are: windrowing, baling, bale collection, bale loading into trucks
and bale transportation. At the factory there are additional steps requiring specialized equipment, viz. unloading, twine removal, debaling, screening and shredding of the trash.

The key concept of the cane-trash burner is that it is a means to achieve what in-field cane burning does, while harnessing the energy released in the burning process. For this to be successful, the movement of the cane with adhering trash (either in whole-stick or billet form) must move through the burner in plug flow, and the residence time in the burner must be short enough to prevent damage to the sucrose in the cane as the leaves are being burnt within the burner.

To utilize a cane trash burner at the factory, cane with adhering trash must be transported to the factory, the trash burnt off the stalks/billets and the 'cleaned' stalks/billets passed on to the shredders in the normal sugar extraction process. In other words, the first operation of conveying from the field to the factory, mentioned above, would be chosen. It is also recommended that the tops should be left in the fields, so as to leave sufficient vegetable matter to preserve the soil health of the harvested field.

**CANE-TRASH BURNER PILOT-PLANT TESTS**

In order to test the concept of burning the leaves off stalks/billets, in a confined space at a controlled throughput, a pilot unit was constructed. The results of these pilot-scale tests are described in a paper by Bernhardt and Arnold (2011). Successful burning of the leaves, similar to that taking place during in-field burning, was achieved in the pilot plant, as shown in Figures 1 and 2.

![Fig. 1. Cane with adhering trash fed to the pilot-plant burner.](image1)

![Fig. 2. Stalks after trash had been burnt off in the pilot plant.](image2)
Conceptual design of full-scale burner

The challenge in translating the CTB concept into reality lies in designing a full-scale burner that can handle the normal throughput rates of the sugar factory. Not only must it be big enough to accommodate the volumes of cane (typically 200-1500 t cane/h, depending on the processing capacity of the factory), this burner must also ensure continuous flow of material into and out of the burner so that no portions of the fed cane are held up in the burner long enough to sustain thermal damage. Pilot tests showed that the residence time in the burner should not be longer than 1 minute.

The conceptual design that could satisfy these constraints is shown in Figure 3. A patent has been registered on this design. The main feature that ensures proper movement of cane through the burner is a series of three staggered, inclined, perforated plates. The inclination of the plates is such that the cane stalks, or billets, slide at a controlled rate down the plates. The length of the plates is such as to give sufficient time for adequate burning of trash to take place. The perforations on the plates have sufficient open area for adequate air flow to ensure complete combustion of the trash.

![Fig. 3. Conceptual design of the full-scale cane-trash burner.](image-url)
The cane with adhering trash, either in the form of whole stalks, or billets, is fed into the burner at the top right (Fig. 3) by a plough that diverts the cane from a conveyor belt onto a spring-loaded plate. The greater the mass of cane on this plate, the more it deflects downward to make the cane slide onto the first inclined plate. At this point, the cane trash is ignited by a gas flame under the first inclined perforated plate. The trash continues to burn as the cane slides down the first inclined plate onto the second and then onto the third. By the time it reaches the bottom of the third plate, all the trash has been burnt and the ‘cleaned’ cane will then exit onto a conveyor at the bottom left of the burner that transports it straight to the shredder.

The ash generated by the burning process drops down through the perforations in the inclined plates, onto the cane on the inclined plate below, from which it trickles through the cane and the perforations in that plate, and sequentially until the final plate where the ash is ultimately collected at the bottom of the burner where it is removed by a rotary valve. This valve not only removes the ash, but also the soil brought in with the cane, which is collected in the same fashion as the ash. The ash and soil can be returned to the fields. It has fertiliser value, mostly in the form of K, P and silica.

The burner is equipped with heat capture facilities, such as an array of tubes carrying water that are heated by the flames of the burning trash.

This concept of a commercial trash burner still needs to be converted into real technology. To prove the concept, an intermediate-scale demonstration burner is currently being built with funding from the South African Government funded Technology Innovation Agency (TIA).

PROGRESS TO DATE

Details of the sliding plates (material of construction, percentage open area, support structures) have been designed and the first plate is currently being fabricated. Measurements will be made of the required angle of inclination and the length of time taken for cane to slide down this plate. From this information, the total length of all three plates can be determined to ensure adequate residence time for complete combustion of the trash (taking into account varying moisture contents).

The combustion gases are currently being studied in separate laboratory tests using purpose-designed laboratory equipment and gas analysis probes.

A computational fluid dynamics model to assist with the determination of air flows in the burner, and the design of energy capture piping, is currently being worked on.

ADVANTAGES AND DISADVANTAGES OF THE CANE TRASH BURNER

The advantages of burning the trash at the mill in a burner prior to normal sugar extraction are:

- There is no need for separate trash collection and processing equipment as when the trash is collected in the field by baling.
- No separate trash feeding arrangement in the boilers is necessary as when trash has been baled and transported to the factory.
- Burning of the trash becomes an integral part of normal sugar extraction.
- No trash storage facility is necessary.
- There is no need for dry cleaning of the sugarcane or baled trash prior to burning. The mineral impurities (soil) are automatically separated in the cane trash burner.
- Beneficial plant nutrients contained in the ash obtained from the burnt trash and collected in the burner can easily be returned to the fields.
- Air pollution due to in-field burning of cane is reduced.

The disadvantages of the cane trash burner are:

- The transport costs of the cane to the sugar factory are increased because of the lower bulk density of cane stalks with adhering trash. This increase in costs is estimated to be about 15-25%, depending on loading procedure, sugarcane variety and moisture content of the trash.
- The cane-payment system will have to be modified to consider the commercial value of the adhering trash. A modified cane-payment system would require intensive work on sampling methods used to determine the amount of trash and its value, which is beyond the scope of this paper.
The cost of the gas used to ignite the trash will form part of the technical investigation of the intermediate-scale cane-trash burner, but it is expected that the gas cost will be relatively small, since burning the leaves of cane stalks will be self-sustaining, as long as cane with adhering trash is fed into the system.

CONCLUSIONS

I have presented the concept of a cane trash burner that simulates in-field burning, but at the same time captures the energy released during the burning process. The burner would be situated at a raw-sugar factory and form part of the normal sugar-extraction process. The energy captured would be used to produce steam, which can find a possible application in generating electricity.

Processing trash in this form has several advantages over separate trash collection in the fields by baling and subsequent transport and processing at the factory.

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Développement d’un brûleur prototype pour la paille de canne

Résumé. Ce papier démontre la faisabilité technique du brûleur de paille (CTB) à l’usine pour brûler les feuilles de canne avant l’extraction du sucre, tout en exploitant simultanément l’énergie produite. Le brûleur pilote original a été testé en 2011. Aucun dommage thermique de la canne n’a été détecté, tandis que les feuilles ont été brûlées dans un espace réduit. Un modèle conceptuel d’un brûleur de canne à échelle industrielle a été développé. Une demande de brevet provisoire a été enregistrée et le financement a été assuré pour construire un brûleur prototype qui sera évalué en août-septembre 2016 ; cette évaluation sera terminée vers octobre-novembre 2016. Les avantages de ce processus industriel sont : (i) la prévention de la pollution atmosphérique qui se produit lorsque la canne est brûlée avant leur récolte, une pratique courante en Afrique du Sud; (ii) l’utilisation de l’énergie produite où l’infrastructure existe déjà pour canaliser cette énergie (chaudières, technologie de production d’électricité) ; la CTB peut être installée dans l’infrastructure existante ; et (iii) la prévention de la manipulation compliquée pour séparer la paille de la canne elle-même. La seule manipulation impliquée serait le transport des cannes récoltées à l’usine ; cela entraînera des coûts supplémentaires en raison de la baisse de masse volumique de canne avec de la paille.

Mots-clés: Paille de canne, électricité, énergies renouvelables, production de vapeur, brûleur
Desarrollo de un prototipo de quemador de residuos cañeros

Resumen. Este estudio demuestra la factibilidad técnica de emplear un quemador de residuos cañeros (CTB en inglés) como parte de la operación de la fábrica (o central) para quemar residuos (hojas de caña) de los tallos antes de la extracción de azúcar, mientras, simultáneamente controlar la energía generada en el proceso de incineración. El modelo piloto original de quemador se probó en el 2011. Eso demostró que no existía daño térmico a los tallos mientras se quemaban las hojas en un espacio confinado para escalar y se realizó un diseño conceptual de un quemador de caña a escala industrial. Se registró una patente provisional y se aseguró el financiamiento para construir un quemador prototipo. Las especificaciones de diseño para el prototipo están en marcha para comisionar en Agosto-Septiembre del 2016. Las pruebas finales del prototipo se han planificado para Octubre-Noviembre del 2016. Las ventajas de introducir la quema la caña en el proceso industrial son, por tanto: (i) el evitar la contaminación del aire que se produce cuando los residuos se queman en el campo antes de la cosecha (que es una práctica común en África del Sur), (ii) el empleo de la energía de la biomasa de los residuos en localizaciones donde existe la infraestructura para aprovechar la energía (calderas, tecnología de generación de electricidad) y la incorporación del CTB al proceso normal de extracción de azúcar puede ser adaptado a infraestructuras existentes, y (iii) evitando la manipulación múltiple de separar los residuos de los tallos, limitando como el único paso de manipulación el trasporte de los tallos, con las hojas adheridas, hasta la fábrica de azúcar, algo que puede significar una disminución del costo en términos de pago de la carga por una menor densidad de bulto de la caña con las hojas.

Palabras clave: Residuos cañeros, energía renovable, electricidad, generación de vapor, quemador