Bioenergy and Bioresource: Open Access, Vol.4, Issue 1, 1-2 Mini Review

Beyond Sugar and Ethanol Production: Sugarcane Residues and Value Generation

Shyna Maes*

Department of Biotechnology, Ghent University, Ghent, Belgium

*Corresponding Author**

Shyna Maes
Department of Biotechnology,
Ghent University,
Ghent, Belgium,
E-mail: ShynaM@Hotmail.com

Received: December 20, 2022, Manuscript No. BBOA-23-84239; **Editor assigned:** December 22, 2022, PreQC No. BBOA-23-84239 (PQ); **Reviewed:** January 05, 2023, QC No. BBOA-23-84239; **Revised:** March 24, 2023, Manuscript No. BBOA-23-84239 (R); **Published:** March 31, 2023, DOI: 10.37532/BBOA.23.4.1.010

Abstract

Sugarcane is the most produced agricultural commodity in tropical and subtropical regions, where it is primarily used for the production of sugar and ethanol. The latter is mostly used to produce alcoholic beverages as well as low carbon biofuel. Despite well-established production chains, their respective residues and by products present unexploited potentials for further product portfolio diversification. These fully or partially untapped product streams are a) Sugarcane trash or straw that usually remain on the fields after mechanized harvest, b) Ashes derived from bagasse combustion in cogeneration plants, c) Filter cake from clarification of the sugarcane juice, d) Vinasse which is the liquid residue after distillation of ethanol, and e) Biogenic CO_2 emitted during bagasse combustion and ethanol fermentation. Utilizing these leftover biomass components to create novel cascade processes might lower final disposal costs dramatically, increase energy output, lower greenhouse gas emissions, and broaden the product range offered by sugarcane mills. In addition to reviewing cutting edge sugarcane bio refinery concepts, this study also makes novel suggestions for increasing the value of leftover biomass. This study is divided into four main sections: i) Cascading use of organic residues for making carboxylates, bio plastic, and bio-fertilizer; ii) Recovering untapped organic residues through anaerobic digestion to make biogas; iii) Valorizing biogenic CO_2 sources; and iv) Recovering silicon from bagasse ashes.

Keywords: • Green House Gas (GHG) • Sugarcane • Bioeconomy • Biofuels • Fertigation

Introduction

Sugarcane (*Saccharum officinarum*) is the most widely produced agricultural product in the world and is grown in tropical and subtropical climates. The two main products it produces are sugar and ethanol, the latter of which is largely utilised to produce alcoholic beverages and low carbon biofuels [1]. However, in addition to the production of sugar and ethanol, there are still unrealized potentials and opportunities for improvement in the sugarcane sector, particularly in relation to environmental concerns related to the treatment of waste products from the industry's traditional process chains.

Sugarcane mills offer various production settings that are targeted at different products depending on the area environment [2]. In contrast, Brazil has fewer independent mills distilleries that just make bioethanol than other countries. Separate sugar mills can be found in various nations that grow sugarcane. The various types of sugarcane mills all have some operating characteristics, such as harvesting, milling, juice clarity, and bagasse based cogeneration, regardless of the product being produced. It is crucial to remember that, depending on the kind of harvesting employed, straw made up of tops and leaves also known as sugarcane trash either becomes accessible as a source of biomass or is burned on the fields prior to human sugarcane harvesting. Due to emissions of particulate matter, the latter one can significantly worsen air pollution. After the sugarcane juice has been clarified, significant discrepancies between independent and annexated mills industrial processes are seen [3]. While the juice in autonomous mills is only utilised to produce bioethanol, annex mills use this raw material in a variety of ways.

Literature review

Despite the maturity of sugarcane processing technology, a greater valorization of waste products in a sophisticated biorefinery setup that employs circular economy principles is needed to address numerous unresolved environmental challenges [4]. Straw, bagasse, filter cake, vinasse, molasses, and CO_2 are six important waste and by products streams in the sugarcane industry. Local air pollution continues to occur as a result of burning cane harvesting, which causes serious respiratory illnesses in the area and increases Green House Gas (GHG) emissions. While theoretically the ash left over from this burning procedure could enhance or retain the quality of the soil, substances created during the incineration also contribute to soil and groundwater contamination (e.g., polycyclic aromatic hydrocarbons).

In many other nations, green sugarcane harvesting is gaining ground whereas burnt cane harvesting is still the most common method in Thailand. Straw that is left on the fields after using this green harvesting method can be utilised as a fuel for AD, which produces biogas. The primary use of bagasse is in boilers or cogeneration units to generate heat and energy for the milling and distillation processes, or in larger plants, to generate electricity that is fed into the grid. Only a tiny portion of bagasse is utilised, especially in smaller facilities, and the remainder presents disposal issues [5]. It is possible to sell excess bagasse, but this depends on the state of the market and the cost of transportation given the distance between the sugarcane mill and potential bagasse users. Press mud, also known as filter cake, is typically applied to fields as fertiliser but is also connected to leaching and GHG emissions when the filter cake decomposes. Alternative usages for filter cakes need to be looked into in order to prevent these negative impacts on the climate and the quality of the groundwater. Fertirrigation, also known as fertigation, is the irrigation of liquids that increases soil fertility. Vinasse is primarily utilised for this process.

However, methane is released when vinasse is temporarily stored in open storage ponds and lagoons, and fertirrigation further degrades the soil quality. For instance, it has a negative overall impact on crop yields by increasing soil salinity and heavy metal accumulation. Molasses made from the manufacturing of sugar has a high energy value and is frequently utilised as a feed additive, a food ingredient, or as a substrate for the production of ethanol. The majority of modern sugar refineries simply emit CO_2 to the atmosphere after bagasse burning and sugarcane juice fermentation. On the other hand, by capturing the CO_2, it can be used as a valuable, renewable supply of carbon for materials applications in a variety of industries as well as, when paired industries as well as, when paired with hydrogen, a renewable fuel for transportation. In addition, geological storage of the biogenic CO_2 from the sugarcane sector is an option for creating negative emission credits.

Discussion

A greater use of circular economy strategies through the cascading use of the aforementioned wastes and residues to develop bio economy concepts could benefit the sugarcane sector [6]. A circular economy seeks to reduce wastes and pollution by keeping products and materials in cascade use to extract the greatest economic value from these by products and to optimise their recycling and reuse, in contrast to the usual take make use dispose strategy of a linear economy. The cascading use of bio based resources is based on a hierarchical, effective use that starts with higher value goods and ends with energy recovery. So, in addition to discussing the cutting edge sugarcane bio refinery, this review also suggests novel methods for further valorizing leftover biomass through cascading use, such as recovering silicon from bagasse ashes, using organic residues in this way to produce carboxylates, bio plastics, and fertilisers, recovering untapped organic residues via Anaerobic Digestion (AD) to produce biogas, and valorizing biogenic CO_2. By adding higher value products, such an upgraded bio refinery strategy could further diversify the offerings of conventional sugarcane mills, increasing their profitability and reducing their reliance on the price fluctuations of rival products based on fossil fuels.

Conclusion

The sugarcane sector has already adopted a straightforward bio refinery idea by diversifying its product line beyond sugar to include ethanol, energy, and, in some circumstances, the manufacture of PLA and biogas. The current study covered further opportunities to advance the circular economy strategy by encouraging improved exploitation of waste and residue streams. Other novel chemical production paths, material exploitation of biogenic silica recovered from sugarcane wastes, as well as CCU/S techniques of CO_2 valorization were consequently included in the review to create an even more diversified portfolio. For the effective deployment of integrated bio refineries in the future, numerous downstream technologies (such as the separation of fermentation products, CO_2 capture units, etc.) need be developed. However, designing and implementing such a complex system is highly difficult. The appraisal of these technologies techno economic viability was outside the purview of this paper, but it is partially examined elsewhere. Nevertheless, when evaluating economic viability, it is equally important to evaluate how to mitigate environmental effects, particularly how to reduce GHG emissions. Therefore, the circular sugarcane economy may play a significant role in defossilizing other industry branches by implementing better CO_2 utilisation or even sequestration that can benefit from the renewable biomaterials obtained by fully utilising the sugarcane wastes and residues to replace fossil resources. But by using proper fertiliser management and fertilisation techniques, recirculating urban mass flows, and cultivating legume intercrops in between sugarcane cropping seasons, long term adverse effects on soil quality can be avoided overall, through maximising the use of sugarcane by-products, wastes, and residues, this paper's discussion of sugarcane value chain extensions, cascading processes, and circular bio economy principles demonstrates how agricultural land valuation still has unrealized potential.

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Cite this article: Maes S. "Beyond Sugar and Ethanol Production: Sugarcane Residues and Value Generation". Bioenergy Bioresour: Open Access, 2023, 4(1), 1-2.