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The generation of residual biomass during the production of bio-ethanol from sugarcane, its characterization and its use in energy production

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ABSTRACT

Sugarcane bagasse is the residue produced by mills after juice is extracted from sugarcane. Other important solid residues in the sugarcane-to-sugar-and-ethanol production chain are the leaves and tops of the stalks (together referred to as cane trash). Although it represents a significant portion of the energy in sugarcane, cane trash is currently left in the fields. This paper has described and analyzed how residues (bagasse and cane trash) are produced from sugarcane and their use as an energy source in the production of ethanol. Also, it presents a review of the physical properties and characteristics of bagasse and cane trash and estimate their energy potential. Bagasse and cane trash have similar fuel characteristics to other biomasses fuels. Special attention should be given to the characteristics of cane trash ash, which has higher fusibility and alkali levels than bagasse. A flowchart of a typical mill was described and the thermal and mechanical energy consumption at various stages of the production process was determined. Of the energy consumed as work, about 58% is accounted for by milling and juice extraction, and 33% by the generation of electricity for use in the plant. In a typical mill using steam generators operating at average pressure and temperature (22 bar, 300–360 °C), about 15% of the bagasse produced is surplus, and an average of 480 kg of steam is used per tonne of cane processed. An energy consumption analysis revealed that there was significant scope for reducing the amount of steam needed to operate the turbines in mills because of the low isentropic efficiencies identified. Cane trash, which is not yet used for energy production, also shows great energy potential because it is produced in similar quantities to bagasse, and its calorific value is only slightly lower.

Contents

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1. Introduction

Sugarcane bagasse is the residue produced by mills after juice is extracted from sugarcane. Over the years bagasse has ceased to be a residue and has become an important energy source, making a knowledge of its properties and characteristics important so that it can be used efficiently in steam generation, gasification, pyrolysis or even as raw material for acidic or enzymatic hydrolysis.

Sugarcane bagasse is traditionally used to generate the steam needed in sugar mills and in ethanol distillation. The Pro-Alcohol program, which began in Brazil in the '70s, was the first major program to replace fossil fuels with a renewable source (hydrous ethanol). At that time bagasse was considered a residue and, as such, needed to be disposed of, which was done by burning it in boilers, thereby generating part of the electricity used by the production mill. Steam was, and still is, expanded in back-pressure turbines to generate electricity to drive the milling tandems and large pumps. Steam from the exhaust turbines is used in the sugar and alcohol production process. Not all plants were able to meet all their own electricity needs because up to the mid '80s electricity production in Brazil was fairly inexpensive and generating capacity far exceeded demand.

From the '90s the cost of electricity began to rise, and mills began to generate increasing quantities of electrical energy until they became self-sufficient, mainly by using steam to generate electricity [1]. Thus, over the past 40 years bagasse has gone from being an unwanted residue to representing an important source of energy, and its importance continues to increase as energy prices on the international market rise.

In the past 30 years, with the increasing demand for and rising costs of electricity, the oil crisis and the possibility of a renewable fuel with lower CO_2 emissions than fossil fuels, there has been renewed interest in the sugar/alcohol industry, and efforts have been made to increase its efficiency so that surplus electricity can be sold. Indeed, this is already happening in some Brazilian sugar and ethanol mills.

Other important solid residues in the sugarcane-to-sugar-and-ethanol production chain are the leaves and tops of the stalks (together referred to as cane trash). Until the '90s, sugarcane trash in Brazil was burned in the fields before the harvest to make cutting the cane and manual harvesting easier. Mechanized sugarcane harvesting was first introduced in the late '90s and has been growing gradually since then, to the point where it now accounts for about 55% of sugarcane production in the state of São Paulo, the largest sugarcane-producing region. Although it represents a significant portion of the energy in sugarcane, cane trash is currently left in the fields.

The search for increased energy efficiency in sugar and alcohol mills is still in its infancy, and much remains to be done to harness the energy from sugarcane bagasse. A knowledge of the characteristics and physical properties of bagasse is essential for the development of any process or equipment using this residue.

The objective of this paper is to review the physical properties and characteristics of the solid residues generated during the production of ethanol from sugarcane (bagasse and cane trash), to evaluate the different ways in which the energy from these residues is used and to estimate their energy potential.

Table 1
Production of sugarcane and sugarcane products in Brazil [4].

Harvest	Sugarcane (tonne)	Ethanol (m^3)	Sugar (tonne)
2007/08	495,843,192	22,445,979	31,297,619
2008/09	563,638,524	27,582,737	31,335,830
2009/10	602,254,167	25,714,732	33,068,261

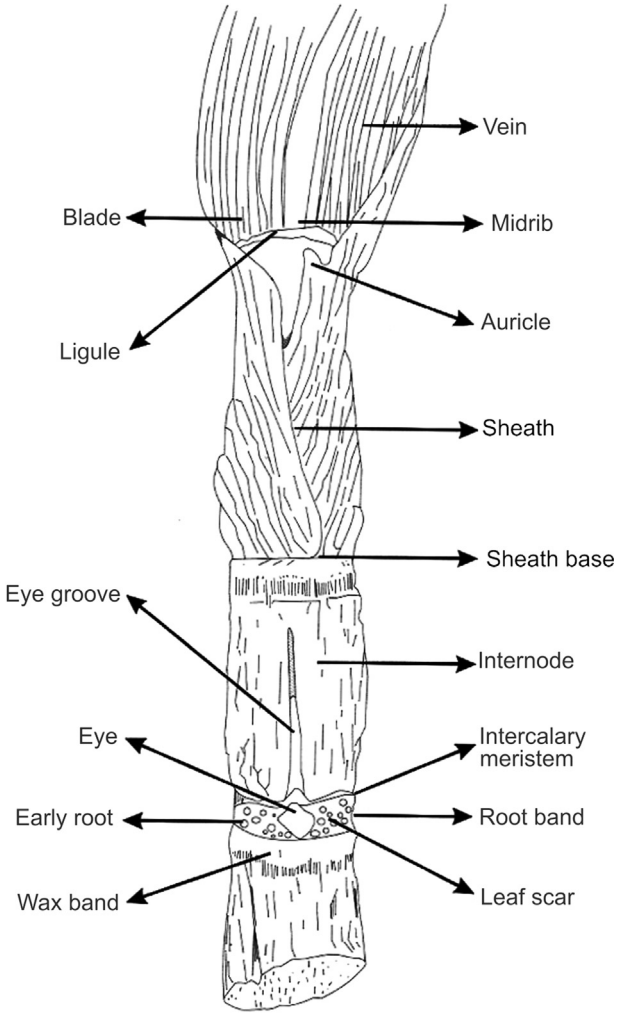

Fig. 1. Structure of a sugarcane leaf [7].