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Agro-industry sugarcane residues disposal: The trends of their conversion into energy carriers in Cuba

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Abstract

The goal of the present work was to carry out a review of the disposal practices for the agro-industry's sugarcane residue and the trends of energy use in Cuba. The lack of an alternative energy carrier to electricity with storage capability for use in off-season has to date been an unsolvable question. The improvement of cogeneration capacity via implementation of CEST or BIG/GTCC and the barriers for their implementation, the introduction of a medium size (3 ton/h) fast pyrolysis module (FPM3) as a solution for off-season energy demand in the agro-industry, and an assessment of the energy required to do so, were also analyzed. Bio-oil production from bagasse and sugarcane agriculture residues (SCAR) and their particularities at the sugar mill are treated. The influence of sugar facility production process configuration is analyzed. The fast pyrolysis products and the trends of their end uses in Cuba are presented. The production cost of a ton of Bio-oil for FPM3 conditions was calculated at 155 USD/ton and the payback time as a function of selling price between 160 and 110 USD/ton was estimated to be from 1.5 to 4 years. The economic feasibility of the FPM3 was estimated, comparing the added values for three scenarios: 1st case, currently-used sugar production, 16.5 USD/ton of cane; 2nd case, factoring in the cogeneration improvement, 27 USD/ton of cane; and 3rd case, with cogeneration improvement and Bio-oil production, 40 USD/ton of cane. The energy use of SCAR and the introduction of FPM3 in the sugar mill are promising improvements that could result in a potential surplus of 80 kW h_e/ton of cane in-season, or 6×10^6 ton of Bio-oil (LHV=15 MJ/kg) for use off-season in a milling season of 4 million tons of raw sugar.

1. Background

Since the early 19th century, Cuba has been one of the biggest sugar-exporting countries in the world. Until 1959 the main market for Cuban sugar was the United States. However, as a result of the political differences between the US and Cuba following the Cuban Revolution in 1962, the US imposed a commercial blockade on trade with Cuba, ending Cuban sugar exports to the US and the sale of US fertilizers, spare parts, transportation equipment, and other goods used in sugar production to Cuba. After the imposition of the blockade, Cuban sugar exports shifted to the former Soviet Union and Eastern European socialist countries. Almost three decades later, in 1991, this market abruptly disappeared with the collapse of Communism in the Soviet Union and Eastern Europe. Since 1991, Cuba has been struggling to rebuild its sugar production and market. It has been a difficult time for the Cuban sugar agro-industry because of the lack of fertilizer, spare parts and other goods. Cuban sugarcane production and its main derivatives from 1980 to 2004 are shown in Fig. 1. It is easy to notice the difference after 1991 when sugarcane production fell, from 80×10^6 to 24×10^6 metric tons in 2004. It is important to add that since the introduction of high fructose corn syrup low calorie sweetener in the 1980s, many Latin America and Caribbean countries exporting sugar have been severely affected by the reduction in sugar

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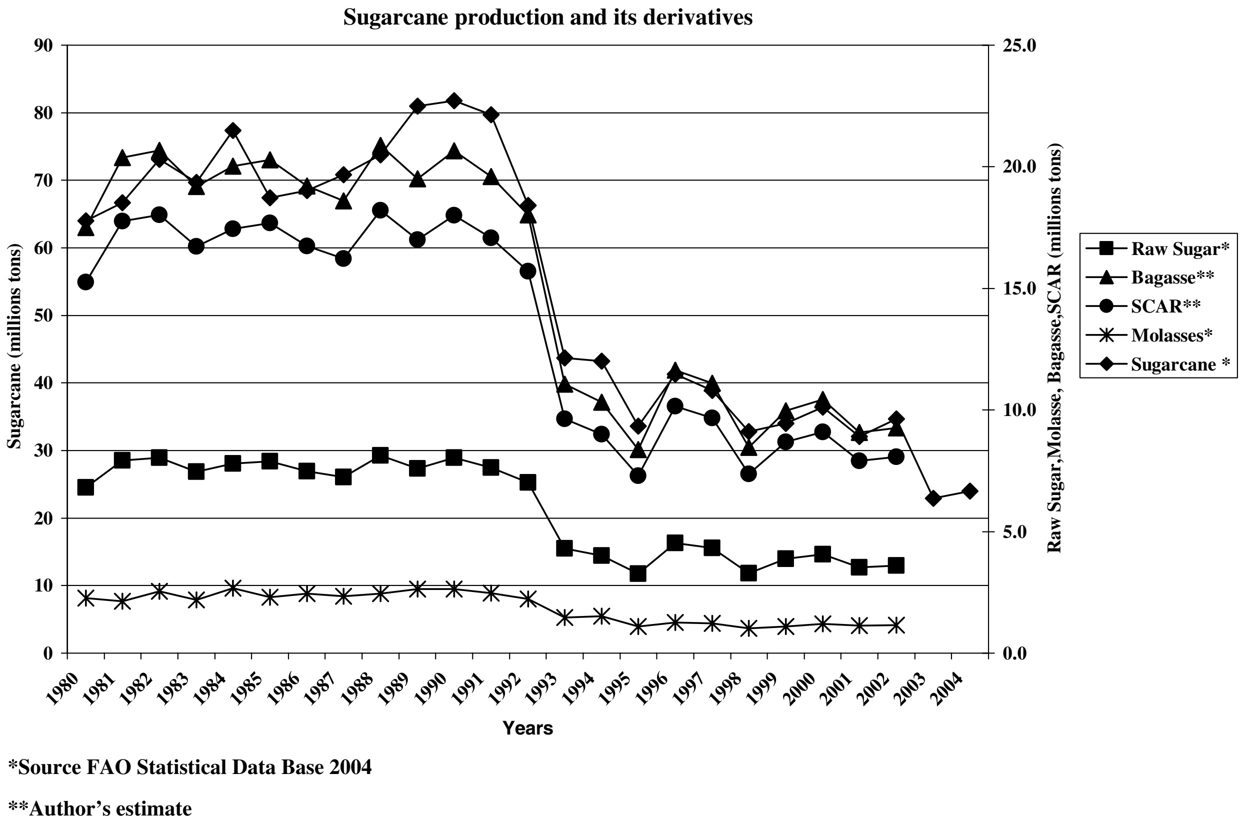

Fig. 1. Production of sugarcane and derivatives in Cuba.

demand in the world market. Corresponding to this situation, starting from 2001 the Cuban sugar industry has gradually downsized. In 1999 there were 155 active sugar mills while in 2004 there were just 85 active mills, with about 600 MW of cogeneration capacity, which is important for the future development of clean energy sources in Cuba.

2. Estimation of residues from sugar agro-industry

A subject of research in several countries around the world today is to find a solution to sugarcane residues as energy sources (Perez, 2004; Chum and Overend, 2001; Scott et al., 1998; Wu et al., 2002; Anselmo Filho and Badr, 2004; Alonso Pippo and Del Rey Ocampo, 2002; Dermibas, 2001). Most authors concur pointing out that the current complex situation demands that the sugar agro-industry undertake important changes. In short, the sugar agro-industry should not focus solely on the production of sugar as its main objective. Instead it should endeavor to become a modern, high-efficiency agro industry with widespread by-product diversification, with the principal by-product being exporting electric power to the grid. Cuba's sugar agro-industry is no exception in this sense. Much of the recent research focuses on the improvement of the sugar production process and the implementation of modern, more efficient cogeneration systems which are able to generate power year-around.

Among the main residues from sugar and ethanol production are sugarcane bagasse and sugarcane agriculture residues (SCAR). Although there are 130 known derivatives from sugarcane by-products (ICIDCA, 1988), about 65 of them (50%) are bagasse derivatives. Sugarcane bagasse is the fibrous waste that remains after recovery of sugar juice via crushing and extraction. It also has been the principal fuel used around the world in the sugarcane agro-industry because of its well-known energy properties (Jenkins et al., 1998; Dermibas, 2004). A ton of bagasse (on a 50% mill-wet basis) is equal to 1.6 barrels of fuel oil on an energy basis. However, the bagasse management and disposal practices employed by the sugar agro-industry have, in most cases, remained the same as those used back in the early 19th century when the factories were designed without regard to energy efficiency (most operate at a low 16–20% efficiency), consuming all of the available bagasse to just meet mill energy demands, resulting in no accumulation of excess bagasse. Regrettably, by this method, the possibility to recover and use an important quantity of energy from bagasse is lost. This waste of a potential energy source is especially unfortunate in underdeveloped sugarcane producing countries where the demand for electric power exceeds the local capacity.

The yield of raw sugar production residues is shown in Table 1. For each ton of raw sugar produced, there are 5.69 ton of residues (wet basis), 45% and 42% of which are bagasse and SCAR, respectively. These statistics under-