SUGARCANE STRAW PROCESSING AND BURNING

The mechanization of the sugarcane harvesting process, in addition to improvements in working conditions and productivity gains, has allowed sugarcane fields to be harvested without burning, with significant benefits to the environment by reducing emissions. The elimination of burning and the increase in mechanical processes have contributed to greater sugarcane straw availability in the field.

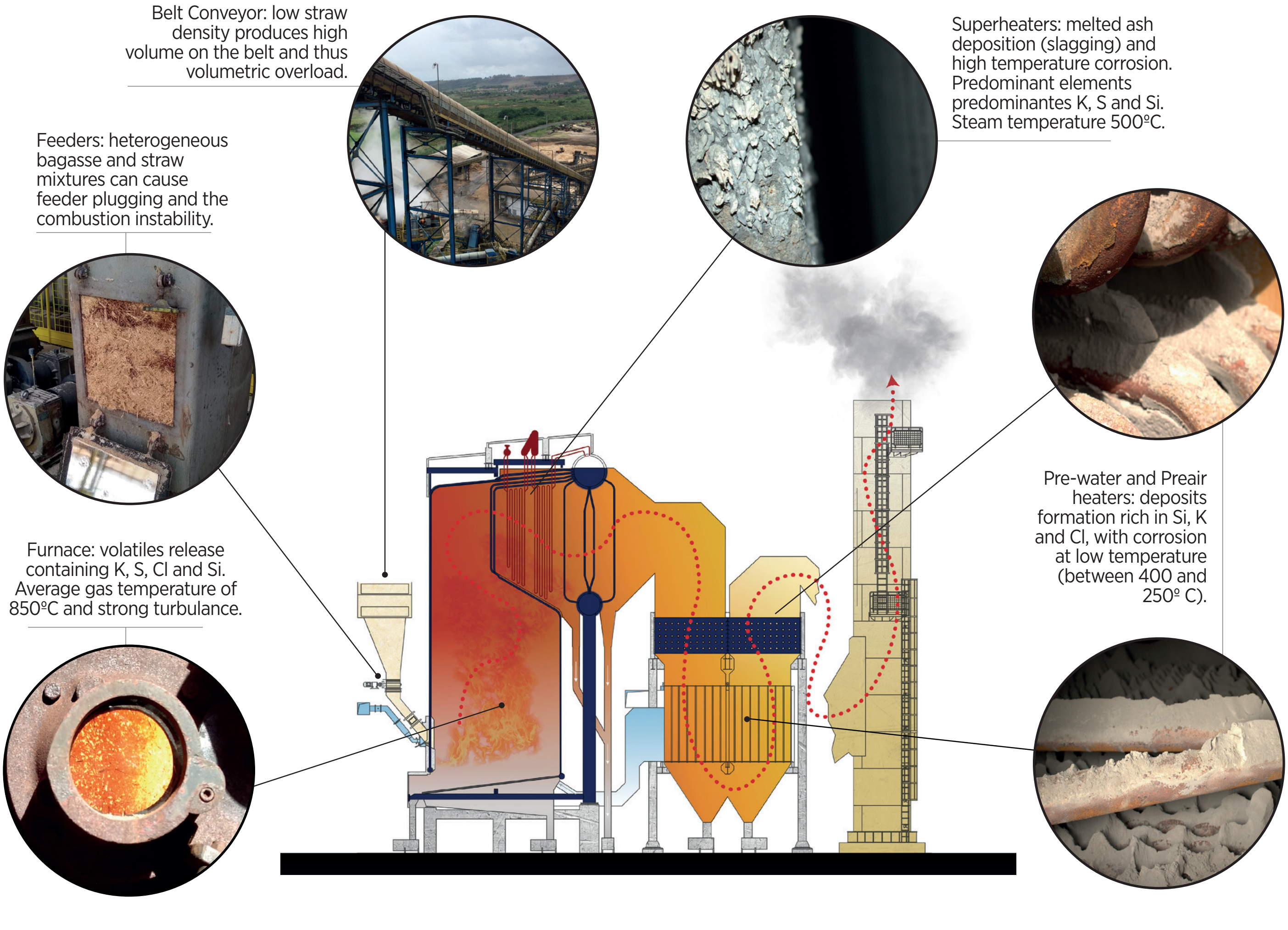
The presence of straw has created profound changes in the production system of the entire sugarcane agro-industrial chain. In addition to creating many opportunities, these changes have brought significant challenges to the sector. Among these opportunities, we highlight the use of straw, in addition to sugarcane bagasse, in increasing the production of electricity at the mills (Leal et al., 2013). The use of bagasse and straw enables the generation, in the current conditions of the existing biomass boilers in the Brazilian sugar-energy sector, of about 0.4 MWh per ton of bagasse at 50 wt% moisture content and 0.7 MWh per ton of sugarcane straw at around 15 wt% moisture content.

This paper, prepared by the SUCRE Project team (Sugarcane Renewable Electricity), presents a critical analysis of the current situation and the main challenges in processing and burning sugarcane straw to generate bioelectricity, based on the experience of the Brazilian sugar-energy industry. This paper addresses the main differences between bagasse and sugarcane straw, in addition to the impacts caused by the use of straw mixed with bagasse as fuel in the boilers. The sugarcane straw processing systems and how these processes can contribute to the increased use of this biomass are also presented. Finally, possible solutions to overcome current barriers and perspectives for the future are presented in this paper.

STRAW AND BAGASSE: IMPACTS IN THE BOILERS

The biomass boilers installed for the generation of steam and electricity in the Brazilian sugar-energy industry were, for the most part, designed and optimized for the use of sugarcane bagasse as fuel. The use of straw in these systems depends on the adequacy of the facilities and the quality and the physicochemical properties of this new fuel, with its comparison with bagasse being inevitable.

Contrary to what was imagined at the beginning of the straw utilization initiatives, this biomass has significant differences in some physicochemical properties when compared to bagasse. The raw straw (before processing) presents pronounced variations in moisture content, depending on the collection system employed (Okuno et al., 2019). If the straw is collected in bales, the moisture level is low (8-18%), but if it is harvested together with the sugarcane stalks and separated in the mill through Dry Cleaning Systems (Soares et al., 2019), the moisture content is high (35-50 wt%) and is near the levels achieved with bagasse (50 wt%) (Leal et al., 2019).



These differences cause the straw to have a wide range of Lower Heating Value (LHV), ranging from 6 to 15 MJ/kg. It also has a high ash content compared to bagasse, and a different elemental composition, with high concentrations of alkali metals, such as potassium (K) and sodium (Na), in addition to a higher concentration of sulfur (S), chlorine (Cl) and silicon (Si). These elements can increase the fouling formation and ash deposits, causing corrosion and wear on the heat exchange surfaces of the boilers.

The chemical composition of ash deposits changes depending on the region of the boiler (Soares et al., 2019). Following the combustion gas flow throughout the different regions of the boiler, the concentrations of potassium and sulfur are higher in the deposits found in the superheater and these levels are lower in regions where the combustion gases are cooler. The concentration of silicon in the deposits, on the other hand, is apparently a consequence of the speed of the gases, as their deposition is significantly increased in low-speed regions. Chlorine concentrations are higher in the cooler heat exchange surfaces of the boilers, such as the economizer and the air preheater, with a more pronounced corrosion process in these regions.

The particle size distribution and density of the straw, when not processed properly, can be quite different from what is found in the bagasse. Thus, the addition of straw to the bagasse can cause adverse effects, such as problems in the boiler feeder, resulting in increased combustion instability.

Due to these impacts, the use of straw in the Brazilian sugar-energy industry is currently restricted to low proportions of this biomass in the mixture with the bagasse, varying between 5 to 18 wt% (dry basis) in the evaluated facilities.

HOW CAN STRAW PROCESSING HELP?

Straw processing is characterized by a sequence of unit operations geared towards adapting the physical and chemical properties of this biomass, minimizing differences in relation to bagasse.

In Brazilian sugar-energy plants that collect straw for the generation of steam and electricity, straw processing systems are generally found. Standard systems are mainly composed of dry sieving and shredding steps. The dry sieving step, which is carried out in a rotary screen, is used to decrease the ash content of the straw by removing inorganic extraneous material. The shredding, in turn, is commonly performed in hammer or knife shredders and aims to reduce the size of the particles, promoting the adequacy of the fuel particle size distribution for the boiler feed system. Although they are essential for the use of the straw, these steps have low efficiencies. Rotary screens have an average of 33 wt% efficiency in removing inorganic extraneous material from the straw and the shredders need frequent maintenance, as they suffer from accentuated mechanical wear and have limitations in the straw particle size distribution suitability. The straw processed in these shredders continues to present coarse and inadequate particles size for the boiler feeders, which increases the risk of obstruction in these systems during feeding.

Instead of using these standard systems, some Brazilian mills have chosen alternative straw processing systems. In these systems, the straw is subject to a washing step in a channel with water, followed by drainage in a cush-cush screen, and finally processed in a mill to reduce moisture and adjust the particle size. In some plants, the washed and drained straw is fed into the last mill of the milling tandem to produce a mixture of straw and bagasse. In other plants, an independent and exclusive milling system was installed for the processing of straw.

Although these alternative systems are still not operating in optimized conditions, the washing process has proven to be promising for the removal of inorganic extraneous materials and chemical elements that that are possible causes of fouling and corrosion in the boilers. Washing promotes, on average, a 44 wt% reduction in the ash content of straw (Soares et al., 2019).

The processing of straw in milling systems presents interesting results (Soares et al., 2019). These systems are efficient in adapting the straw particle size distribution to the desired standard, with greater operational regularity, lower energy consumption, lower maintenance costs and lower investment required for the installation, when compared to conventional shredders.

POSSIBLE FUTURE SOLUTIONS AND PERSPECTIVES

Studies carried out in the SUCRE Project indicate that one of the ways to overcome some current barriers that limit greater use of straw for the production of bioelectricity is the implementation of an optimized washing system, coupled with milling systems for the processing of straw.

After five years of studies, carrying out tests and evaluations at partner mills, bench testing and laboratory analysis, SUCRE has developed some proposals to improve the efficiency of straw processing (SUCRE, 2019). The proposed configurations aim to improve the quality of the straw, enabling greater use of this biomass in the mixture with bagasse to increase the bioelectricity generation potential of the Brazilian sugar-energy sector.

The proposed project enables the conditioning of straw separated by the Dry Cleaning System or baled straw. The first step involves pre-washing the straw, which is important for the removal of coarse inorganic extraneous materials (soil, sand). Then, a first drainage stage is carried out on a cush-cush screen, followed by grinding in an independent mill with the addition of imbibition water between 50° and 60°C, which removes part of the unwanted impurities and chemical elements, in addition to adjusting the straw particle size to improve the efficiency of the next stage. Then, the straw is directed to an extractor that operates with a mechanical agitation process to effectively remove impurities and critical chemical elements such as K, Na, S, SiO_2 and Cl. Then, the straw is subjected to a second drainage stage in a cush-cush screen and, from this stage, SUCRE proposes three possible configurations. In the first configuration, for plants that have idle milling capacity, straw is fed into the last mill of the milling tandem and mixed with bagasse; in the second configuration, the straw is milled in an independent mill and is added to the bagasse on the belt conveyors; and in the third configuration, the straw is ground and mixed with a part of the bagasse produced, using an independent milling system. For more conscious consumption, all the water used in the process must be treated in a closed circuit and reused, allowing low rates of replacement of this resource.

The expectations with the SUCRE proposals are quite optimistic. According to laboratory studies, an optimized washing process could promote the reduction of ash content by more than 74 wt% and of critical chemical elements such as chlorine (93 wt%, d.b.), sulfur (16 wt%, d.b.), potassium (82 wt%, d.b.) and silicon (62 wt%, d.b.).

In conclusion, the alternatives proposed by SUCRE may allow greater use of straw for the production of bioelectricity, overcoming some of the current barriers. The production of more homogeneous bagasse and straw mixtures, with standardized moisture content and particle size distribution and lower concentrations of inorganic extraneous materials and chemical elements harmful to the boilers, may allow the use of a higher proportions of straw in the mixture with the bagasse, exceeding the current values, reducing boilers damages.