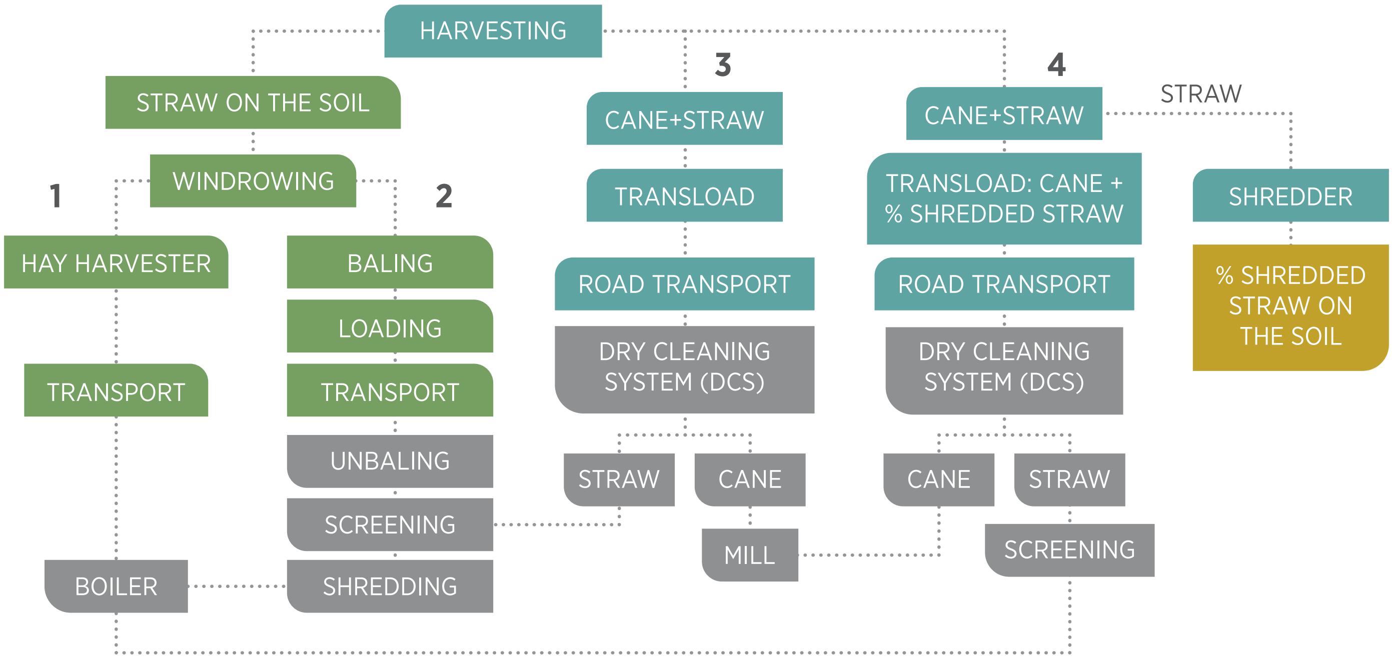
SUGARCANE STRAW RECOVERY ROUTES



This work describes the sugarcane straw recovery routes, before related to vegetal impurities, currently seen as a co-product of sugarcane, with emphasis on the processing of shredded straw. The equipment involved in this route was improved, through virtual prototyping techniques, with biomass modeling, a specialty of the SUCRE Project team.

The adoption of the mechanized system of harvesting sugarcane, without burning, produces a large amount of vegetal waste, the straw, which is separated from sugarcane through the harvester's primary and secondary extractors, which can also be used as a complementary fuel to bagasse.

During SUCRE Project, the four straw recovery routes in the field shown in the figure below were tested and analyzed.

In general, the bulk straw recovery route and the straw recovery route by baling involve the following agricultural stages: after the sugarcane harvesting and before the windrowing operation, straw is kept in the field between 4 and 15 days for drying. Fifteen days after harvesting the tillage operations are prioritized, competing with the straw recovery.

The windrowing is normally of the triple type, which has three passes of the rake to form a single windrow. With two passes, two adjacent rows are formed, and the third pass joins the two rows, forming a single row. SUCRE Project evaluated the path of mineral impurity and determined that, in the conventional harvesting of chopped cane, the amount of soil (mineral impurities) in the cane increases by up to 4 times, and then there is an additional increase of almost 3 times in the straw windrowing field operation, in experiments carried on the Project.

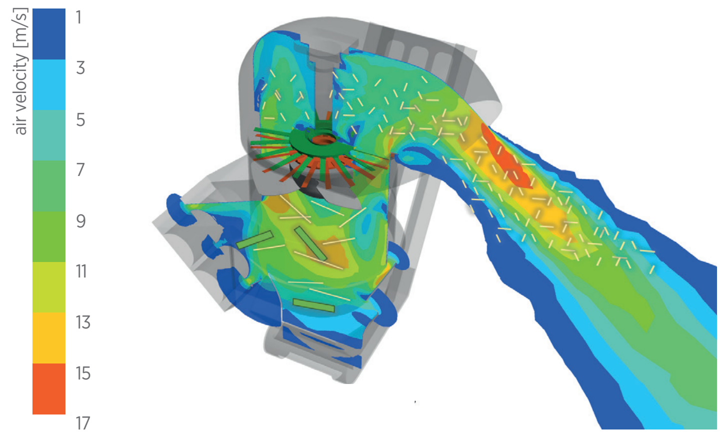
After the straw is heaped, in Route 1, the hay harvester machine travels over the rows of straw, recovering, chopping and transfer the straw to trucks or transloader trailers, which move alongside the hay harvester. Trucks unload this straw directly into the mill's bagasse stock yard, forming a mixture of bulk straw and bagasse.

Route 1 has presented in the test a field capacity of 16.8 t/h; fuel consumption of 3.3 l/t; load density of 93 kg/m^3; in addition to a recovery efficiency of 31%, and a mineral impurity index of 16% in the loaded straw.

The Hay Harvester spends around 70% of its time operating in the field recovering straw but is stopped by choking 21% of the day working hours. Therefore, this equipment must be adapted by the manufacturers to improve its performance in the field with sugarcane straw.

In the Baling system (Route 2) baling operation also begins after the windrowing, when the baler recovers the straw contained in the windrows, compresses it and ties it with longitudinal twines to transform it into prismatic bales, with around 500 kg each. The next operation consists of collecting the baled material, which is carried out by the bale-recovering cart. The cart groups the bales into piles and transfers them to the edge of the sugarcane field, from where the bales are loaded onto the semitrailer with the support of a forklift, to be delivered in the reception of the bales processing plant in the industry. Field tests have shown that balers have an average field capacity of around 40 t/h, with around 10% of straw in moisture content, with a fuel consumption of 1.21 l/t, incorporating in the straw close to 18% of soil, for a maximum recovery efficiency of 46%.

Route 3, integral harvesting, does not require the windrowing process because it does not recover straw from the ground. Instead, during the harvesting operation, straw is not separated from cane billets, or only partially removed, by the harvester extractor fans, but is directed



Straw Shredder, coupling CFD and DEM

to the transloader along with the cane. The advantages are the elimination of all subsequent straw harvesting operations, whether by bales or bulk (hay harvester), the reduction of mineral impurities due to the fact that the straw has no longer contact with the soil, and the immediate release of the harvested area for the subsequent tillage operations, in addition to independence from the climate, no longer requiring 4-15 days of sunshine to dry the straw.

In order to assess the impacts of straw recovery with integral harvesting (Route 3) on the technical indicators of harvesting, transloading and transport, tests were carried out to quantify the influence of the primary extractor rotation speed of the chopped sugarcane harvester on the amount of vegetal and mineral impurities in the load, sugarcane visible losses, fuel consumption and potential field capacity of the harvester. Four treatments were established with the following primary extractor speeds: 650, 750, 820 and 900 revolutions per minute (RPM).

The treatments showed expected results, since the greater the cleaning (straw removal), the lower the mass harvested per unit of time, that is, they showed that 4% less of straw in the load between extreme fan speeds, 20% increase in density, resulting in an additional 12 t in the transported weight.

Test results showed that higher extractor speeds resulted in visible losses 2.5 times greater than at lower speeds.

The primary extractor at 650 RPM reduces the fuel consumption by 30%, when compared to the 900 RPM case, 0.88 and 1.26 l/t respectively.

According to this research, the reduction of the primary extractor speed to 650 RPM in the sugarcane harvester allows a greater amount of straw to be transported with the cane billets, but this strategy increases the transport cost due to the reduction in the load density.

SUCRE Project established Route 4 of shredded straw recovery, aiming to reduce the critical items present in integral harvesting (Route 3), which are, low density of the load transported to the mill, greater need for equipment in the harvesting fleet, especially transloaders, and low efficiency of the Dry Cleaning System (DCS) in the industry.

Integral harvesting with shredded straw (Route 4) foresees the implementation of a straw shredder (Figure above), which is mounted on the primary extractor of a commercial chopped cane harvester, chopping all sugarcane straw material that is blown by the primary extractor, through one set of rotary knives/counter-knives.

This device allows cane to be harvest with simultaneous processing of the straw (separation and shredding) directly in the field. The main purpose of the shredder is to reduce the straw particle sizes, so that it can occupy empty spaces between cane billets in the load of the transloader, thus allowing to carry a larger amount of straw without decreasing the density of cane + straw, transported and delivered to the mill. With shredded straw it was also expected to increase the operating efficiency of the conventional Dry Cleaning System (DSC).

The assessment of the impact on the DCS efficiency was done in a partner mill. A comparison between shredded straw and conventional straw (straw processed by chopped sugarcane harvester in the conventional way) was made.

In the configuration for removing 50% of the straw available in the sugarcane field, preliminary results of the test at the partner mill demonstrated that DCS had an increase in cleaning efficiency of about 67% operating with shredded straw (from 9 to 15%). It should be pointed out that the percentage of straw in the load was 27% higher, from 7% to 9% vegetal impurity, in conventional and shredded straw, respectively. Due to the very low efficiency of the tested DCS, this result shall be considered only as an indication of a trend and not as a representative value.

Regarding the load density (kg/m^3) transported to the mill, an increase in vegetal impurity (straw) of the transported load was observed during field tests. Shredded straw, with smaller particle sizes, occupies the empty spaces, while load with conventional straw, originating from the harvester without straw shredder, shows a larger size of straw particles, having a greater impact in reducing the load density.

In the case of the recovery of 50% of straw available in the sugarcane field, that is, when the amount of straw in the load was reduced by 50%, although the load density has been reduced by 5%, from 345 to 328 kg/m^3, it was found that vegetal impurities increased by 38.8%, from 7.2 to 9.9%, therefore, this extra amount of shredded straw is responsible for a small reduction in the load density.

Another legacy of SUCRE Project is the indication of necessary improvements in the straw processing equipment, aiming to increase the performance of these components in the future, with their development by the manufacturers, indicated by the virtual prototyping, computer simulation, prepared by LNBR specialists.

The use of virtual prototyping with the aid of CFD (Computational Fluid Dynamics) and DEM (Discrete Element Method) techniques, improved the performance of the straw shredder, mounted on a chopped sugarcane harvester, and theoretically increased the efficiency of the Dry Cleaning System (DCS) equipment, in its conventional and alternative versions.

With these simulations, models and scenarios of DCSs, taking advantage of this legacy of SUCRE Project, manufacturers of this type of equipment in the market can now decide which is the best option to improve the performance of their DCSs, in partnership with mills who own these models.

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