INNOVATIVE SOLUTION FOR SUGARCANE STRAW RECOVERY

Luigi Pari[1], Simone Bergonzoli[2], Manoel Regis Lima Verde Leal[3], Jorge Luis Mangolini Neves[3]
[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per l'ingegneria agraria - Monterotondo (Rome-Italy)
luigi.pari@crea.gov.it. Phone: +39 0690675249.
[2] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per l'ingegneria agraria - Treviglio (Bergamo-Italy)
simone.bergonzoli@crea.gov.it. Phone: +39 036349603.
[3] Laboratório Nacional de Biorrenováveis/Centro Nacional de Pesquisa em Energia e Materiais (LNBR/CNPEM), – Campinas, (São Paulo, Brasil).
regis.leal@lnbr.cnpem.br. Phone: +19 3518-3170

ABSTRACT: Brazil is a major sugarcane (Saccharum officinarum L.) producer and its production more than doubled over the last decades to meet global bioenergy demands for reducing crude oil dependency and mitigating climate change. With the progressive shift from a burned to a non-burned harvest system, most of the straw presently retained on the soil surface has become economically viable feedstock for bioenergy production. Large-scale bioenergy demand has triggered new approaches to straw management in Brazilian sugarcane fields in fact, straw is a promising feedstock for bioelectricity and cellulosic ethanol in Brazil since has become available in large quantities in the field. Straw can be used as fuel for cogeneration systems of sugarcane mills to increase surplus electricity for commercialization. However, the exploitation of straw potential is still limited due to some challenges related to its agricultural harvesting. In this work, two innovative solution for straw recovery are proposed to increase the quality of the biomass reducing the ash content and simplifying the harvesting value chain. The first possibility evaluated the change of the windrowing process technique, from the traditional one to the belt windrower. The second possibility studied was the baling of the straw biomass directly from the harvesting machine, directing one fan of the cleaning system into the baler that follows the harvesting machine. The two harvesting systems proposed tackle the problem providing a solution at the present bottlenecks. However, further studies will be needed to provide scientific evidence of the solutions proposed by acquiring experimental data during straw harvesting field test
Keywords: agricultural residues, bioethanol, sugar cane, renewable energies, mechanization

1 INTRODUCTION

Sugarcane is one of the most important crops in the world and due to its large diffusion in Brazil, this country has become the largest producer of sugar. Sugarcane, even if is cultivated mainly for sugar production generates also other interesting by-products to be considered in line with a circular economy approach.

In fact, Brazil is nowadays the second largest producer of ethanol in the world and bagasse is largely used in the sugar production plants as energy source due to their high primary energy content per Mg of biomass.

Bagasse (the industrial fibrous residue from the juice extraction) is basically all combusted in the boilers to provide energy required for their functioning. Straw (also known as trash) is normally burned in the pre-harvest step. The common practice of burning the sugarcane straw is spread especially in facilities with non-mechanized on-field operations (i.e. manual harvesting) with the aim to facilitate harvest and transport operations and costs.

Nowadays, due to environmental, agronomic and economic reasons, the manual harvest of sugarcane has been gradually replaced by mechanical practices with disposal of straw on the ground, in a system called green cane management that makes straw available for other uses. In industry, straw can be used for second-generation (2G) ethanol production and/or bioelectricity generation, constituting an important part of the energy matrix.

The green management of sugarcane produces large amounts of straw placed on the soil after each harvest, ranging from 10 to 20 Mg of dry matter per ha.

In the field, sugarcane straw promotes soil conservation, preserves moisture and reduces erosion, thus enhancing crop yield. For this reason and in order to preserve soil quality, even if straw could represent an opportunity for bioenergy production an adequate level of this biomass should be maintained on the soil.

Despite the large energy potential associated with the sugarcane straw, very little efforts have been made so far to establish an appropriate harvesting rate and logistic chain to exploit such potential.

Similarly to corn stover in the US [1], for sugarcane straw to become a real feedstock for large biorefineries, an innovative logic chain covering collection, storage and transportation should be develop to ensure biomass quantity and quality. As the attention has been mostly towards the harvesting of the cane stalks, it is still not clear for the industry the best way to collect the straw for energy applications [2]. In fact, until the end of the 80's, the only concern of sugar cane growers was the amount of cane stalks produced in the field [3].

Many authors have studied the technical parameters and economic impacts of different straw recovery systems, being the solutions mostly focused on two different paths: integral harvesting routes and baling. In the integral harvesting route, the straw is harvested and transported together with sugarcane stalks, while in the baling route, the straw is left to dry in the field for about 2 weeks after sugarcane is collected. The straw is then windrowed, collected and compacted into bales, which are subsequently loaded and transported to the mill separately from the stalks.

Each of the two systems have pros and cons. The baling system allows the straw to be recovered with less moisture and in a compacted form, which facilitates transportation and storage and reduces the respective costs; however, possible damage to the ratoon and the soil compaction are important disadvantages as well as the high ash content of the biomass deriving from windrowing. The integral harvesting system is based on reducing the speed of the harvester primary extractor which, in turn, increases the amount of straw transported with the sugarcane and reduces losses. This system also reduces soil compaction, since fewer machines are involved. However, higher straw moisture and lower load density are unfavourable aspects of integral harvesting [4].

While relevant studies on these two recovery systems have been. carried out on the importance of maintaining the straw in the soil for environmental reasons, defining the right quantity of biomass to be removed, innovative logistic chains able to supply sugarcane straw of quality at competitive costs are still not defined.

The paper studied two technical solutions for the improvement of biomass quality, more concretely for the reduction of ash content in the biomass. Two possibilities have been explored. The first possibility evaluated the change of the windrowing process technique, from the traditional one to the belt windrower, in order to decrease the quantity of soil transported into the bales and therefore biomass ash content. The second possibility studied was the baling of the straw biomass directly from the harvesting machine, directing one fan of the cleaning system into the baler that follows the harvesting machine. The top leaves and the straw discharged from the second fan are directed into the soil, as normally done, to maintain a portion of biomass in it. The first approach allows to reduce the ash content of the bales without changing the current logistic chain as well as ensuring the drying of the biomass in the field before windrowing. The second approach decreases the field traffic by avoiding the windrowing and the baling operations since the loose biomass is baled directly after harvesting.

2 MATERIAL AND METHODS

The research consisted in a preliminary technical study based on field data and mainly on data acquired on previous research activities with the aim to reduce ash content in sugarcane straw. The approach followed wasto study the problem of straw harvesting from a holistic point of view, given by the experience of the authors, by the large number of published paper and report studied and from data acquired during straw harvesting. The study of previous researches highlighted the problem of defining a harvesting system able to reduce the impact on the soil, maintain the right quantity of biomass in the soil and to reduce the ash content in the straw collected. Two different solution were defined on the basis of the approach above described and compared with the existing one in order to define pros and cons. For each of the two technical solution identified the new configuration of the value chain was studied and described. For one of these, a simplified technical design was developed in order to describe the harvesting technique since is not present on the market a machine and no experience exist on this solution.

3 RESULTS AND DISCUSSION

Two technical solutions for the improvement of biomass quality, more concretely for the reduction of ash content in the biomass were identified.

The first possibility consists in the change of the windrowing process technique, from the traditional one to the belt windrower, in order to decrease the quantity of soil transported into the bales and therefore biomass ash content.

Figure 1: Traditional windrower

Figure 2: Continuous windrower

The main difference compared to traditional rake is represented by the pick-up system: the rake lifts the crop in order then to transport it on a conveyor belt, whereas traditional rakes drag the crop on the ground up to the windrow. This difference leads to:

- lower product losses. During crop dragging traditional rakes tend to leave on the ground a part of product. On the opposite, with the continuous merger the biomass is lifted on a belt and it is not dragged on the ground as it usually happens with traditional rakes;
- less damages to fresh growth of crop. Under normal conditions, already after some days from harvesting the crop produce fresh growth made up of small stalks. Under these conditions, rotary-rakes tend often to break the small stalks, causing a delay in growth and therefore in harvesting.
- Less ash content in the biomass. The raking system allows to avoid collection of ground and stones that goes into the biomass and into the bales.

Adopting this solution, no variation in the actual harvesting value chain will occur but only a modification in the windrowing system, so the drying of the biomass will happen in the field.

The second possibility studied was the baling of the straw biomass directly from the harvesting machine, directing one fan of the cleaning system into the baler that follows the harvesting machine (figure 5). The direct baling is already a commercial system applied to harvest some residual biomass such as the wheat straw [5]. The system is very interesting and promising because it speeds up the harvesting process, reduces the field traffic and increase the quality of the biomass by avoiding the contact between straw and soil.

Figure 3: Mechanical harvesting

Figure 4: Traditional baling

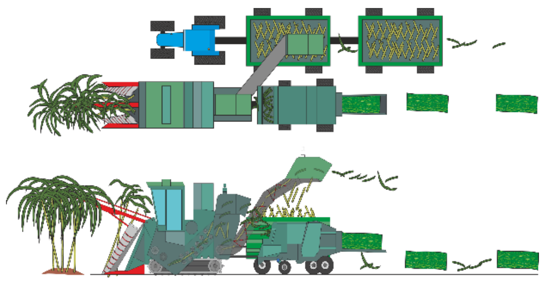

Figure 5: Direct baling

The top leaves and the straw discharged from the second fan are directed into the soil, as normally done, to maintain a portion of biomass in it. This approach decreases the field traffic by avoiding the windrowing and the baling operations since the loose biomass is baled directly after harvesting. Some experiences of integral harvesting were already carried out, but the straw was collected with the billets of the cane and a mechanical separation of the two biomasses was necessary in the sugar plant [4]. Also, the threshing of the straw was studied in order to decrease the bulk density of the biomass directing the trash with the billet or into the soil [6]. The solution proposed, differently from the others previously developed, is designed to:

- lower the ash of the biomass.The contact between the soil and the straw is avoided.
- maintain the baling system. The value change will continue by baling the biomass.
- allowing the storage of the biomass. Differently for harvesting the loose biomass, the storage will take place normally by piles of bales.
- reduce the field traffic. Only the harvesting/baling operation will occur without necessity of windrowing.

4 CONCLUSIONS

The sugarcane straw is a very interesting biomass considering the high availability per hectare, the diffusion of the crop in the world and energy production potential. The exploitation of such a biomass will foster the production of bioenergy and mainly of 2G ethanol with a huge impact on greenhouse gases reduction. Actually, the sugarcane straw is still untapped since the change from manual to mechanical harvest is a recent process and is still in progress in many areas of the world. For that reasons some bottlenecks are still present in the value chain. The right quantity of straw to be maintained into the soli for soil fertility is not well defined as well as the system to harvest it.

The results of the research highlighted the complexity of the sugarcane harvesting. Different aspects are involved in the task: the environmental aspects of soil fertility and compaction, the quality of the biomass and the storage of the biomass. The two straw harvesting systems proposed tackle the problem providing a solution at the present bottlenecks. Further studies will be needed to provide scientific evidence of the solutions proposed by acquiring experimental data during straw harvesting field test.

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