Main processes of mechanization of biomass from sugarcane: An approach using agriculture 4.0

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ABSTRACT

Faced with the great problem of petroleum fuels, it is essential to invest in new clean energy sources. This scenario promotes the search for new raw materials and sustainable routes that can be used alternatively, such as the so-called biomass, materials rich in plant or animal organic matter. In this context, the biomass obtained from sugarcane stands out. It has been used in various ways, from a natural input to obtain sugar and molasses production to an energy source to obtain ethanol, a renewable fuel. Thus, in view of the great potential of sugarcane, the present work consists of a conceptual literature review, addressing the main challenges in its production in Brazil, and exploring Agriculture 4.0. The main results of the study demonstrate that the adoption of Agriculture 4.0 and, consequently, the mechanization of sugarcane harvesting are not only urgent needs, but must also be carefully implemented to bring more benefits to the companies involved in its production.

Keywords: Biomass, Sugarcane, Agriculture 4.0, Mechanization.

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INTRODUCTION

Sugarcane biomass is a vital source of fuel in the Brazilian power grid. Generally, 7% of the total energy limit introduced in the country is generated from both sugarcane bagasse and plant contamination (Energy Research Company, 2018). The latter alludes to the crowns of the sugar cane, dry and green leaves wrapped inalienably in the sugar cane that follow after the harvesting tasks.

In addition, the Brazilian sugarcane area has undergone some long-term changes, most notably the elimination of pre-harvest straw consumption (usually in the State of São Paulo) due to a variety of monetary, social, and ecological issues. This reality has pushed the sugarcane area towards mechanical-based agrarian tasks in the Center-South district of Brazil, especially those identified with collection and planting (Cardoso *et al.*, 2018; Menandro *et al.*, 2017).

This progress over the past few years has brought testimony to a lot of biomass in the sugarcane fields, framing a straw on the surface of the earth. While mulching can benefit prolonged soil quality and crop profitability, such accumulation also addresses an important feedstock for biorefinery and confers new freedoms to the Brazilian sugarcane industry (Carvalho *et al.*, 2017; Junqueira *et al.*, 2017; Klein *et al.* ., 2017).

A new report led by the Sugarcane Renewable Electricity Project (SUCRE) has assessed the conceivable extra flow force for Brazil's Center-South region, which so far accounts for 93% of the complete sugarcane handled in Brazil. The results showed that, considering the use of half of the straw effectively accessible in the sugarcane plantation, an additional 35 Terawatt-hours (TWh) could be negotiated with the Brazilian matrix annually, with the possibility of supplying energy to about 28 million families in the nation (SUCRE, 2017).

Certainly, bioelectricity can play a significant role in supplementing hydropower and decreasing the age utilization of the fossil base force, particularly in the Center-South. In the dry season, when hydroelectricity is scarce, sugarcane harvesting begins and energy can be generated from bagasse and straw to meet the energy requirement. In addition, sugarcane plants are close to the habitats of the heap, thus inferring a decrease in transmission misfortunes (Khatiwada *et al.*, 2012; Scaramucci *et al.*, 2006). Energy from biomass cogeneration is similarly more important than fossil-based nuclear power plants with respect to reducing GHG outputs (Evans *et al.*, 2010).

The capacity of this source is obvious and considerable work has been done in using sugarcane biomass for energy generation. In Brazil, the considerations identified with the cogeneration of energy from sugarcane bagasse have been accounted for since the latter part of the 1970s (Moreira *et al.*, 1977), when sugarcane mills were upgrading their cogeneration innovation to produce overflow power to the grid. More recently, different examinations in the country have revealed the potential benefits of this type of biomass, zeroing in on the relief of the impacts of environmental changes (Dias *et al.*, 2012; Moreira *et al.*, 2016; Seabra and Macedo, 2011; Silva *et al.*, 2014).

Freely, other ongoing evaluations have addressed the potential benefits of utilizing surplus bioelectricity from sugarcane bagasse as an extra source for the national grid in India (Hiloidhari *et al.*, 2018), Australia (Renouf *et al.*, 2013), Thailand (Suramaythangkoor and Li, 2012), South Africa (Mashoko *et al.*, 2013; Petersen *et al.*, 2018), Mauritius (Brizmohun *et al.*, 2015; Khoodaruth and Elahee, 2013), Jamaica (Contreras-Lisperguer *et al.*, 2018), Belize (Gongora and Villafranco, 2018), among other tropical nations.

Despite the fact that there is immense potential to realize the widespread use of sugarcane biomass as a significant source of energy in Brazil, there are still numerous specialized, monetary, and administrative difficulties to be overcome by the sugarcane business before transmitting such potential to the trellis. One of the numerous difficulties is identified with the scenario of the Brazilian sugarcane industry, which has faced a basic financial circumstance with the increase in the obligation and shutdown of mills throughout the country since the last global financial emergency (Canal Energia, 2018; Mendonça *et al.*, 2012). Thinking about the configuration of the sugarcane business, large-scale green field projects (i.e., new tasks committed to sugar, ethanol and power generation) in Brazil are still identified as a high danger from the point of view of the business visionary.

In this specific circumstance, evaluating the technical and financial practicality of new tasks in the sugarcane business area becomes particularly essential to assist in an exact dynamic interaction, uniting the local exploration area, the private area and the strategy and leadership. In addition, abnormally zero techno-monetary evaluations of the capacity of sugarcane straw for the generation of bioelectricity in Brazil are scarce in the country. The primary distributions that evaluated these options were recently barred by Cardoso *et al.* (2015) and Cardoso *et al.* (2018), whose reviews focused on the impacts of straw recovery considering modern green field plants. Recently, an examination was barred to carry out a constant investigation of innovations in straw recovery in brownfield plants (Sampaio *et al.*, 2019); In any case, the techno-monetary investigation was specific to the structure of the bundle.

Therefore, this work contemplates the retrofit enterprise, that is, a stable enterprise with less use of capital in the existing factories, to raise the monetary possibility of straw recovery using the vital framework, whose subtleties about innovation will be additionally detailed. The models and reproductions that support the evaluation of agrarian and mechanical structures were developed by the Virtual Sugarcane Biorefinery (Bonomi *et al.*, 2016). This system was created and updated over the last decade by the National Biorenewables Laboratory (LNBR), an examination body that is part of the National Center for Research in Energy and Materials (CNPEM).

An impressive number of articles dependent on the underlying information from the VSB have been distributed in the local scientific area over the long term. The vast majority of distributions are identified with the evaluation of first and second age biorefineries (Cavalett *et al.*, 2017; Junqueira *et al.*, 2017; Watanabe *et al.*, 2016a, b), creation of n-butanol (Mariano *et al.*, 2013; Pereira *et al.*, 2015), use of vinasse for anaerobic processing (Moraes *et al.*, 2015, 2014), as well as different evaluations identified with varied strategies, innovations in biorefineries and bioproducts (Klein *et al.* , 2018, 2017; Rivera *et al.*, 2017).

Sugarcane, in addition to being part of Brazilian history, is also an excellent source of energy, being clean and renewable. From all these attributes, it is possible to understand why sugarcane is one of the most important agricultural crops for the Brazilian economy. Since the beginning of Brazilian history, sugarcane has been used in the most diverse ways, natural, as an input to obtain sugar, for the production of molasses and, more recently, to obtain alcohol fuel, for which all the product is used, even bagasse, in order to obtain the maximum possible energy. (Neves *et al.*, 2003; Silva, 2007).

Thus, due to the great usefulness of sugarcane, there is a great increase in the crops of this crop, which has provided a great and rapid growth of several sectors of the Brazilian production chain, with obvious and notorious emphasis on inputs, machinery and equipment, not to mention the generation of jobs through the use of labor, either directly or indirectly. (Segovia, 2004).

Taking into account the vast areas that are occupied by the planting of sugarcane and the enormous progress expected for the near future, there is an obvious progression in the process of mechanization of crops, especially that of sugarcane, in a process similar to what happened with soybeans.

This process of mechanizing crops and harvests is supported by the lack of labor, caused by the rural exodus, which increases labor costs, the increase in production values and also so that it is possible to follow the law, which prohibits burning sugarcane fields before the harvest takes place. Mechanical harvesting originated in the mid-1940s, in view of the lack of workers. At first, the equipment harvested the canes completely, leaving them in groups that weighed between 750 kg and one ton. As technology evolved, in the mid-1970s, the first harvester appeared, model CH200, which harvested chopped sugarcane, speeding up the process of transporting the harvest, performing both tasks. This type of harvesting came to transform the concepts of sugarcane harvesting, as they were previously known, taking into account that several pieces of equipment manufactured in Brazil began to be used, but which had imported technology. (Ripoli; Villanova, 1992).

In this way, it can be seen that mechanical harvesting is already used by the main companies in the sector, taking into account that it allows cutting, separating and loading the sugarcane, all in a single process, making it faster and, therefore, speeding up the transport of raw materials to the industries without losing the quality of the cultivated product. (Magellan; Braunbeck, 1998).

The sugarcane producing sector intends, in the near future, to leave the harvesting of the sugarcane crop completely mechanical. Thus, in the Brazilian southeast, 40% of the plantation is harvested in this way, even though there are differences in this percentage between the producing companies. The companies that have a lower percentage than the one mentioned above are those that are based in a more rugged terrain, which does not allow or hinders the use of this equipment. However, the new companies are already setting up their plantations in locations that allow for mechanization.

Throughout this period of great mechanization of the agricultural industry, it is necessary to make an analysis of all the parameters that govern the use of this equipment, from the varieties of sugarcane that will be used for planting to the investment in this equipment and the necessary hiring of labor.

With regard to the varieties available for planting, there are programs for the genetic improvement of Brazilian sugarcane and producers are increasingly aiming to increase the quality and productivity of the product, as well as the possibility of mechanizing these processes, both planting and harvesting. These systems can also be observed through state initiatives, such as the sugarcane program – IAC, and in the private sector, such as the CTC, the sugarcane technology center. Both programs focus on allowing new crops to be mechanized.

Therefore, this article seeks to show the main concepts of the so-called agriculture 4.0 and those related to the processes of mechanization of sugarcane, specifically with regard to the varieties available for mechanization, the machines and specific labor, in order to demonstrate the benefits of this advance in technology and the improvements obtained for the product and respective derivatives of this process.

CHALLENGES OF THE AGRICULTURAL SECTOR

It is well known that the population is growing: in the coming decades, the population is expected to grow by 33%, reaching almost 10 billion in 2050, compared to the 7.6 billion recorded in October 2017. By 2100, the global population is estimated to reach 11.2 billion. However, this figure may underestimate actual fertility rates – in other scenarios, the population could reach 16.5 billion. Population growth will increase the demand for food, even against a backdrop of modest economic growth, by 50% compared to 2013 agricultural production.

Meanwhile, the global diet is also changing, as a result of changing demographics: there is a growing demand for high-value animal protein, a trend that, in addition to natural population growth, is being driven by urbanization and rising incomes.

It is also known that urbanization is increasing, and by the mid-2050s there could be a net addition of 2.4 billion people to cities. Urbanization spurs improvements in infrastructure, such as chains that enable the trade of perishable goods. It also tends to increase incomes, increasing demand for processed foods, as well as animal foods, as part of a broader food transition. Annual per capita meat consumption is projected to reach 45.3 kg per person in 2030, up from 36.4 kg between 1997 and 1999.

But there is a downside to richer diets, especially those with excessive meat consumption. In developed countries, a lack of fresh food, dependence on fast food (many of them meat-based) and processed foods have led to a crisis in childhood obesity and alarming numbers of people suffering from chronic diseases such as diabetes, high blood pressure and heart problems. In fact, chronic diseases account for nearly half of the world's burden of disease, creating a double burden when associated with infectious diseases, which are still the leading cause of disease in developing countries.

Simply put, it's obvious that more people mean higher demand, and that demand, in turn, implies higher production. Farmers will have to produce 70 percent more food by 2050, according to the Food and Agriculture Organization of the United Nations (FAO). And that food will need to be customized to the needs of a growing urban population, a factor that spans the entire value chain of agriculture.

While agricultural investments and innovations are increasing productivity, yield growth has slowed to very low rates. The question arises: who will cultivate? Even though food needs and demand are increasing, the rural population is shrinking. In addition, rural populations are aging rapidly, which has important implications for the labor force, production patterns, land tenure, social organization in rural communities, and overall economic development.

In addition, the world's agricultural land is becoming increasingly unsuitable for production: based on certain metrics, 25% of all agricultural land is already classified as highly degraded, while another 44% is moderately or slightly degraded. Water resources are highly compromised, with more than 40% of the world's rural population living in water-scarce areas.

Land has long been recognized as a finite resource, but sometimes degraded farmland was simply replaced by others, bringing in new unused land for cultivation. Such land is rare nowadays, and what is left often cannot be cultivated sustainably. Landlessness has resulted in smaller farms, lower production per person, and greater land scarcity – all of which contribute to rural poverty.

Agriculture is a primary – and indirect – cause of farmland degradation, with different agricultural aspects contributing to this process through a variety of ways. In this context, the process of soil erosion is caused by excessive cutting of vegetation (clearing of agricultural land), along with inadequately orchestrated rest periods, crop rotation, and excessive grazing of livestock.

Approximately 80% of global deforestation is driven by agricultural concerns. And while removing vegetation to make way for farmland is necessary to prevent soil degradation, it also indirectly contributes to water erosion. This last point is worth noting: while irrigation systems maximize efficiency of use, growing populations make water security and scarcity a real concern. The investment considered necessary by 2050 is US$ 1 trillion for irrigation water management in developing countries alone.

All of these issues are a result of poor foresight and planning. Land scarcity and income poverty, along with unsustainable land management practices, are direct causes of the degradation mentioned earlier. This is how farmers are driven to cut down forests, cultivate steep slopes without conservation, overgraze, and make unbalanced fertilizer applications. One project estimates that an investment of US$160 billion will be required for soil conservation and erosion control.

Another concern of the agricultural sector is climate change. Climate change is a fact – and it's rapidly altering the environment. The degree of synthetic greenhouse gas (GHG) emissions has reached the highest rate in history, according to a 2014 report by the Intergovernmental Panel on Climate Change (IPCC).

Agriculture is a major producer of GHGs: Over the past 50 years, greenhouse gas emissions from agriculture, forestry, and other land uses have nearly doubled. Agriculture contributes the largest share of global methane and nitrous oxide emissions. And projections suggest a further increase by 2050.

A side effect of climate change is an increase in rainfall variability and the frequency of droughts and floods, which tend to reduce crop yields. Although higher temperatures can improve crop growth, studies have documented that the agricultural yield of a crop decreases significantly when daytime temperatures exceed a certain specific level (FAO, 2016e).

Climate change will affect all aspects of food production and agricultural inputs: increased rainfall variability and more droughts and floods are likely to reduce yields. Climate change will contribute to current long-term environmental problems, such as groundwater depletion and degradation, which will affect food and agricultural production systems. Without efforts to adapt to climate change, agricultural insecurity will increase substantially. There will be an impact of change in global food security not only on food supply, but also on food quality, access and utilization.

SUSTAINABLE DEVELOPMENT

Sustainable development has come to the forefront of the scientific debate and the political agenda. The World Commission on Environment and Development, known as the Brundtland Commission (1987), proposed the broadest definition for sustainable development and has since rightfully earned its place in the vision, mission and strategy of organisations, venues and governments. Sustainable agriculture is widely discussed and is seen in the international forum as essential for the transition to global sustainable development

Sustainability in agriculture is related to the ability of an agroecosystem to predictably maintain production over time. A key concept of sustainability, therefore, is stability under a certain set of environmental and economic circumstances that can only be managed on a site-specific basis.

If the perspective of sustainability is a bias against the use of biological and chemical technology and adopts an all-natural ecosystem, agriculture, as a practice, is already excluded. If, on the other hand, the perspective of sustainability is the preservation of non-renewable resources within the scope of the agricultural enterprise, the objective is not only achievable, but also good business practices and good environmental management.

An equally unnatural and parallel phenomenon has been the exponential growth of the human population, with associated demands for food and shelter often exceeding the earth's natural carrying capacity.

Based on the premise that human population growth will not be constrained as a result of food shortages due to the overstepping of societal values, technology plays a key role in sustainable agriculture, including:

(i) increased agricultural productivity;

(ii) sustainable agricultural practices;

(iii) the basis for sustainable agriculture.

Sustainability includes the purpose of food production, the well-being of food producers, and the preservation of non-renewable resources. To this end, technology of all kinds has been and will be the artificial component that will make it possible to link these objectives.

In fact, history confirms that technology has been essential for agricultural productivity and stability; Current advances in technology confirm that the discovery and development of new technologies is a sustainable endeavor, and common sense leads us to the conclusion that technology will enable sustainable agriculture.

Innovations in agricultural technology are the cornerstone for satisfying the new demand for food, standardized and useful products. Not only the products, but the production process must meet recognized quality criteria and standards. Technology in agriculture is also the solution to minimize negative impacts and better adapt to climate change.

TECHNOLOGY IN AGRICULTURE

Efficiency and productivity will increase in the coming years as "precision agriculture" becomes more widespread and farms become more connected. It is estimated that by 2020, more than 75 million agricultural IoT devices will be in use: the average farm will generate 4.1 million pieces of data daily in 2050, up from 190,000 in 2014.

However, while the growing number of connected devices represents a huge opportunity for producers, it also adds complexity. The solution lies in making use of cognitive technologies that help to understand, learn, reason, interact and increase efficiency. Some technologies are more advanced than others, but the innovations hold great promise. Here are some of the key technological innovations predicted for the near future:

Internet of Things (IoT): Digital transformation is changing the agricultural world. IoT technologies make it possible to visualize the correlations of structured and unstructured data to provide insights into food production. IoT platforms, such as IBM's Watson, are applying machine learning to data from sensors or drones, turning management systems into true AI systems.

Skills and workforce automation: By 2050, the UN projects that two-thirds of the world's population will live in urban areas, reducing the rural workforce. New technologies will be needed to ease farmers' workload: operations will be carried out remotely, processes will be automated, risks will be identified, and problems will be solved. In the future, farmers' skills will increasingly be a mix of technology and biology skills, rather than purely agricultural.

Data-driven agriculture: By analyzing and correlating information about climate, seed types, soil quality, disease likelihood, historical data, market trends, and prices, farmers will make more informed decisions.

AGRICULTURE 4.0

The traditional approach to the food industry is undergoing a fundamental transformation. The first technological revolution in agriculture brought impressive advances: between 1961 and 2004, cereal production in East Asia grew by 2.8 percent per year, or more than 300 percent during the period, made possible by modern agricultural practices, including irrigation, the use of fertilizers and pesticides, and the development of new and more productive varieties of crops (World Bank, 2008). However, efficiency gains are decreasing: the yield rate is decreasing. And the challenges are greater: the world needs to produce 70% more food by 2050, using less energy, fertilizers and pesticides, while reducing GHG levels and dealing with climate change.

Old technologies must be maximized and new ones created, improved, and utilized. It's called Agriculture 4.0, the next agricultural revolution, which must be green, with science and technology at its core. Agriculture 4.0 will need to consider both the demand and value chain side as well as the supply side, with the equation of food scarcity, using technology not only for the sake of innovation, but to improve and address the real needs of consumers by re-engineering the value chain.

Modern farms and farming operations will function differently, primarily due to advancements in technology, including sensors, devices, machinery, and information technology. The agriculture of the future will use sophisticated technologies such as robots, temperature and humidity sensors, aerial imagery, and GPS technology, just to list a few of the possibilities.

These advancements will enable businesses to be more profitable, efficient, safer, and environmentally friendly. Agriculture 4.0 will no longer need to rely on the excessive application of water, fertilizers, and pesticides to all fields. Instead, farmers will use minimal amounts, or even remove them altogether. They will be able to grow crops in arid areas and utilize abundant, clean resources, such as the sun and seawater, to grow food.

The good news is that these digital technologies are taking over the industry, improving the entire food value chain. Agricultural Technology *startups*, according to Agfunder, have grown more than 80% annually since 2012. Agritech startups are on the rise, with entrepreneurs and investors showing a voracious appetite for the sector.

According to the concept of European Agricultural Machinery (2017), agriculture has also developed five stages in the development process:

(i) Agriculture 1.0 appeared at the beginning of the twentieth century, a labor-intensive and low-productivity agricultural system;

(ii) Agriculture 2.0, widely remembered as the Green Revolution, began in the late 1950s, when agronomic management practices such as supplemental nitrogen and new tools such as synthetic pesticides, fertilizers, and more efficient specialized machinery allowed them to take advantage of relatively inexpensive inputs, dramatically increasing production potential and increasing returns to scale at all levels;

(iii) Agriculture 3.0, its focus shifts from pure efficiency in terms of cost reduction to profitability, which can be seen as objective and creative, looking for ways to reduce costs and improve quality or develop differentiated products;

(iv) The evolution of agriculture 4.0 occurs in parallel with similar evolutions in the industrial world, where it is branded as industry 4.0. Therefore, the term agriculture 4.0 is often used in agriculture. In terms of definitions, agriculture 4.0, in analogy to industry 4.0, represents the integrated internal and external network of agricultural operations. This means that there is information in digital format for all agricultural sectors and processes; communication with external partners, such as suppliers and end customers, is also carried out electronically; and the transmission, processing, and analysis of data are automated.

Agriculture 4.0 paves the way for the next evolution, including today's operation without human devices and based on direct systems that can make automatic decisions.

To the end of this topic, we bring the studies of Tien *et al.*:

> Agriculture 4.0 implies connotations of both cultures, animals (possibly a broader understanding of fisheries and forestry) for research, transfer and production. Modern agriculture interested in sustainability and safety solutions. Agriculture is implementing techniques such as tillage, sowing, pruning, crop rotation, cultivation, harvesting, with the aim of achieving higher productivity, better protecting the environment, and based on the progress of digital technology.

VARIETIES OF SUGARCANE

It is well known that the price of oil increases and has an immediate impact on the price of gasoline. In addition, Brazil has already developed technology for the creation of flex-fuel engines, which makes it possible to choose between alcohol and gasoline for use in the vehicle, which results in an increase in the demand for alcohol

The higher demand for alcohol also implies a higher production of fuel, which, consequently, requires more production of the fuel's raw material, i.e., sugarcane. In this context, programmes for the improvement of agricultural raw materials play an important role in the creation of new and more productive varieties.

Every year, new varieties appear on the market, all promising more yield, higher production, and greater ability to adapt to the mechanical process. Currently, those responsible for the new Brazilian varieties are the CTC (Sugarcane Technology Center), the IAC (Agronomic Institute of Campinas) and the RB (Ridesa).

Growers have more than 50 cultivars at their disposal, if we add up everything that is produced by the three companies mentioned above, and thus they can choose the variety that best adapts to the climate and soil they have.

According to Togo and Casagrande:

> The choice of sugarcane varieties to be cultivated is of paramount importance for the producer, so he must be aware of a set of characteristics that will be fundamental for the productivity of his sugarcane fields, such as: higher production per unit of area, better adaptation to the cultivation region, better agro-industrial characteristics, resistance to diseases and pests and, Obviously, aptitude for mechanized harvesting.

Furthermore, according to the studies by Landell *et al.* (2006), certain peculiarities of the available varieties need to be analyzed in detail, so that it can be evaluated which one has better performance according to the land in which it will be grown, the local climate, its fertility, cation and water retention, among other factors.

These characteristics of the cultivation terrain are essential for the choice of the variety to be grown by the company and will also determine the correct time for harvesting, aiming to extract the maximum potential from production. In addition, it is important to note that the diversification of cultivated varieties is of paramount importance to avoid diseases and/or pests.

The old epidemics of diseases such as coal and mosaic serve as a warning for companies to realize the risk they run by keeping their raw material in only a few varieties.

On this point, Togo and Casagrande argue:

> "In this regard, it is suggested that a variety, no matter how good it may be, should never occupy more than 20% of a company's sugarcane fields. In this context, the large supply of varieties currently on the market serves to minimize the risks of epidemics, since the genetic base of plants is more diverse. To get an idea of the situation, in 1984, the introduction of a new disease to which the NA56-79 variety (the main variety at the time) was susceptible would have the potential to destroy 42% of the national crop. In 2003, the introduction of a new disease that affected the main variety could harm only 15% of the sugarcane fields."

With regard to the suitability for mechanized harvesting, the cultivation of sugarcane must possess certain specific characteristics, such as size, straightness and resistance to cutting, so that the plant and its natural spreading are not disturbed. These characteristics are of paramount importance to facilitate the operation and need to be considered when planning the variety to be chosen by companies.

Other factors that must be taken into account are the ripening period and the useful period for industrialization, which are also important to ensure a standard maturity throughout the harvest (Pereira; Torrezan, 2006).

THE MACHINES

According to Neves *et al.*, 2003, the use of mechanical harvesters is more common in different systems for agro-industrial production. With regard to sugarcane cultivation, 30% of the plantation is harvested by machines (Pearce, 2006).

In addition, according to Ripolli and Ripoli (2004), two types of machines are available on the market, namely, those that harvest the whole sugarcane and those that harvest the sugarcane in pieces. In general, you end up opting for the latter type, as it is more effective for cutting, loading and transporting the cane.

According to Magalhães and Braunbeck (1998), there is an increasing interest in harvesting sugarcane through chopped sugarcane harvesting equipment, especially in places where the terrain allows it and where there is little labor. After all, this equipment cuts, fractionates, cleans and transports the sugarcane in a single process.

However, for all this to happen successfully, it is necessary to observe some peculiarities that will make the harvest more productive. Pereira and Torrezan (2006) report the following requirements:

1) Analyze which machine is going to be used in the harvest, so that it can be verified how much space will be needed in the crop, so that it is ideal for a mat or tire of the machine to pass, without spoiling the plants and allowing the plant to sprout in a more tamed soil.

2) Thoroughly check the types of irregularity of the terrain, such as ravines, holes, furrows, etc., as well as obtain the level of compaction of the terrain and its depth.
3) Completely level the ground, so that it is easier to cut the sugarcane without the blades of the equipment having contact with the soil, so that impurities, both mineral and vegetable, that may come into contact with the sugarcane are minimized, so that losses of the industry as a whole are also reduced.
4) Select the types of variety that are most conducive to the mechanized system, that is, that have peculiarities such as a straight bearing, resistance to cutting and natural debarking, so that cleaning tasks are easier and the amount of undesired residues is reduced.
5) Analyze the slope of the terrain in order to choose the best equipment, knowing that for the treadmill type the slope should be a maximum of 14% and for those with tires, it should be a maximum of 18%, in order to avoid accidents.
6) Design the fields and carriers of the plantations according to the slope of the land, in order to increase productivity, especially if using transshipments to avoid wasting time with many unnecessary maneuvers.

Mechanical harvesting makes it possible to establish a standard for processing sugarcane, which in itself creates a sense of security in the production process. This, consequently, significantly improves the control of cutting activities, allowing them to adapt to the fast industrial pace. In addition, it reduces the environmental problems arising from the burning of sugarcane fields, which used to be so common, which results in a reduction in labor instability and a substantial increase in the area to be harvested (Ustulin; Severo, 2008).

According to the studies of Rodrigues and Saab (2007), the process of mechanization of agriculture, specifically that of sugarcane, is an advance from which there can be no escape. All changes with regard to cutting are not just substitutions of one process for another. In fact, it is a set that involves the process of preparing the soil in the plantation, with the use of new machinery in agriculture, and this must involve the entire workforce, from those who deal with the cutting to the employees who receive the sugarcane as raw material in the factories.

In addition, it is worth noting that the use of equipment by entrepreneurs in the agricultural sector is a fundamental habit for this sector to be modernized (Veiga Filho, 1994). Starting from this agricultural modernization that brings with it technological advances to the sugarcane niche, it is noted that the manual worker ceases to exist, giving way to the employee who operates the equipment. This results in a more qualified and better trained workforce for a more modern and demanding market.

THE OPERATOR

According to Silva (2007), the mechanization of sugarcane production requires the equipment operator to behave in a new way in relation to their functions. The use of these new types of equipment requires the employee to adapt, update and acquire knowledge to operate these machines. On the other hand, however, this allows for greater safety in work processes.

In this context, in order for the employee to perform their duties successfully, it is necessary to analyze some parameters that are essential for the service to be developed in the best way. These include:

1) Have technical knowledge about the functionalities of the equipment, so that the employee can deal with any problem that may occur and know how to differentiate all the functions available on the machine. Examples include seat adjustment, climate control and communication systems. (SKOGFORSK, 1999);
2) Have technical knowledge of the position of the cut and the hands, taking into account that the employee is the one who decides the operation so that the cut is carried out and it is the cutting process that manages to make the impurities that come together with the product fall. In the same way, the employee also needs to know how to cut the base of the product, which should not exceed a height of 100 mm, so that problems do not occur in the clogs.
3) Responsibility and discipline are also important characteristics for employees to be able to operate successfully, especially if you take into account that there will be several professionals who will operate the equipment, specifically during the harvest period, which also influences the calculation of the period worked.

Thus, according to Pereira and Torrezan (2006), the success of the sugarcane harvest carried out mechanically depends, ultimately, on the quality of the service provided by the employee. Therefore, they must be well prepared and receive training in order to provide greater gains for the company, since a well-trained professional will cause less damage to it. Thus, it is understood that training and professional qualification systems are vitally important to reduce industrial costs, allowing the harvest to be carried out with more quality.

FINAL THOUGHTS

Throughout the present work, it was realized that the adoption of Agriculture 4.0 and, consequently, the mechanization of sugarcane harvesting are not only urgent needs, but must also be carefully implemented to bring more benefits to companies. As mentioned, if the planning criteria for the selection of varieties, adaptation of the terrain, hiring and preparation of labor, among other parameters, are not followed correctly, they can result in losses for the company. On the contrary, if they are followed, they can bring benefits and even increase productivity, and, consequently, profit.

Thus, it can be seen that a good selection of the varieties that will make up the company's production, the appropriate choice of equipment, which will provide a more agile and accurate harvest, and the frequent preparation and training of the employees who will operate the machinery are of paramount importance for the mechanical harvesting of sugarcane to be balanced.

Bioelectricity from sugarcane straw can be economically viable in any scenario, considering the numerous difficulties in achieving a cleaner electricity grid in the country. In the investigation carried out for the best stable situations (activity during the off-season), the internal returns were 35 to 69%, 44 to 83% and 54 to 99% per year, considering plants with single beating limits of 2, 4 and 8 million tons of sugarcane per year. Due to the work situations during the sugarcane harvesting season, the internal rates of return were identified with ranges of 6 to 19%, 8 to 22% and 10 to 25% per year, respectively.

These results demonstrate the practical feasibility of extending this innovation to contribute to advances towards cleaner production, always favoring the benefits of existing plants. Certainly, the transition from sugarcane straw to bioelectricity helps reduce greenhouse gas emissions, especially by replacing sources such as fossil gasoline, which are regularly used during the sugarcane harvest in the south-central region of Brazil.

As presented in this article, this path to practical improvement will firmly depend on elements such as farm management, existing equipment in each plant (hardware idle limit), scale of operation, operating period, distance from the vehicle with straw, and energy cost. The use of straw during the off-season implies practical and stable enterprises, although situations that operate only during the sugarcane harvest season are less attractive, mainly due to the higher investment cost arising from the extension of modern equipment.

It is important to note that some factories in Brazil have idle capacity in boilers and turbines, making it practical to recover extra straw during the season. The investigation of the effects showed that, although the efficiency of the Distributed Control System (DCS) is identified with a large scope of vulnerability that influences the activity in real factories, its effect on the financial results was smaller than the observed impacts of different limits evaluated in this study. So, again, the cost of selling energy is a key variable in the supervision of straw recovery projects in Brazil. Further investigation, however, is important to fully analyze the effects of straw recovery on the viability of gradual operations in the sugarcane business. For a more comprehensive evaluation in future studies, more information should be collected in both agricultural and mechanical experiments to determine the effects of straw removal on sugarcane profitability, on the costs of modern support and especially in boilers, and in addition to evaluating several advances in straw expulsion, such as the structure of the bunch.

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