Shahid Bahonar University of Kerman

Biomechanism and Bioenergy Research

Online ISSN: 2821-1855
Homepage: https://bbr.uk.ac.ir

Iranian Society of Agricultural Machinery Engineering and Mechanization

Monitoring and Estimating Sugarcane Losses during Harvesting Using Sound Analysis

Amin-Reza Jamshidi[1]✉, Mohammad-Amin Asoodar[2], Sasan Ahmadi[3]

[1]Department of Agricultural Mechanization, Kerman Branch, Islamic Azad University, Kerman, Iran.
[2] Department of Agricultural Engineering, Ramin Agriculture and Natural Resources University of Khuzestan, Ahvaz, Iran.
[3] Faculty of Agricultural Mechanization, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran.

✉ Corresponding author: aminrezajamshidi@gmail.com

ARTICLE INFO

Article type:

Research Article

Article history:

Received 11 May 2023

Received in revised form 13 June 2023

Accepted 20 June 2023

Available Online 30 June 2023

Keywords:

Acoustic sensor, Closed circuit camera, Harvest losses, Microphone, Recording.

ABSTRACT

Mechanical harvesting of sugarcane is done in two ways: green and burnt, and usually burnt harvest has between 25-50% less losses. When harvesting sugarcane, the sound of sugarcane pieces hitting the wall of the primary extractor hood can clearly be heard. Accordingly, it was decided to use the audio system to determine the relationship between these sounds and the losses of the primary extractor. To record sounds in the basic extractor, two models of full-directional and one-way capacitive microphone (cardioid) and Cool Record Edit Deluxe and Audacity software were used. To detect the wavelength of the sounds caused by the collision of different parts of sugarcane with the hood cap and extractor blades by throwing a large volume of straw along with 25 cm pieces of sugarcane billets, a sound record was set. A camera was also installed there to record the video of what was happening under the extractor compartment. The results showed that the one-way capacitive microphone installed in the upper part of the primary extractor housing received clearer sounds. Analyzing the recorded sounds and comparing them with the images obtained from the camera under the primary extractor revealed that the audio loss detection system detects the losses in the primary extractor with an accuracy of about 75 to 80%. The loss rate at 1200 rpm was about 1.5 times higher than the loss rate at 1100 rpm.

Cite this article: Jamshidi, A. R., Asoodar, M. A., & Ahmadi, S. (2023). Monitoring and Estimating Sugarcane Losses during Harvesting Using Sound Analysis. *Biomechanism and Bioenergy Research*, *2*(1), 40-47. https://doi.org/10.22103/BBR.2023.21485.1042

Publisher: Shahid Bahonar University of Kerman
DOI: https://doi.org/10.22103/BBR.2023.21485.1042

INTRODUCTION

Considering Iran's climatic and territorial potentials, the production capacity of agricultural products is more than 300 million tons, while with all the efforts made; now only 100 million tons of agricultural products are produced per year. Such a condition indicates a distance from the scale of optimization of production and economy in the agricultural sector. Therefore, it is not produced as much as the capacity and the result will be an increase in prices. At the end of the Fourth Economic, Social and Cultural Development Plan of Iran, assuming that 30% of losses remain constant, about 33 million tons of agricultural products will be converted into wastes, the value of which is estimated at about $ 8.9 billion. This amount can provide food for 20 million people, while 25 to 30 percent of the total populations are vulnerable in terms of energy, 10 percent of them suffer from severe nutritional deficiencies (Pallathadka et al., 2023).

Sugarcane (*Saccharum officinarum* L.) is one of the strategic crops of Khuzestan province, Iran, which is cultivated on more than 100,000 hectares of irrigated lands. High biomass production leads to high losses for this crop. A part of this loss is related to the production conditions of the crop on the farm and another part is related to the processing of sugar production in the factory. In the agricultural sector, the use of tools and machinery during the planting, growing, and harvesting stages play an essential role in increasing or decreasing the volume of losses. Planting stage losses mainly include losses of machines cuttings, physical and biological damage of setts; diminish growth of setts, improper soiling of collection, replanting, and gap filling (Maleki & Jamshidi, 2011). In the growing stage, the losses are due to late harvesting of the field and consequent delay in ratooning, improper execution of ratooning operations and heeling-up and cultivator, different dimensions of furrow and ridge in the field, and destruction of sugarcane stumps during ratooning.

In other case, (Kosum & Bun-art, 2020) showed that sugarcane losses from the operation of harvesters are as follows 49% from base cutter, 26% from rollers, 17% from elevator and 8% from primary extractor. The loss of sugarcane from the transport fleet on the way to transfer sugarcane to the factory and also the delay in harvesting burnt sugarcane and its transfer to the factory are losses whose quantitative and qualitative losses are noteworthy (Tweddle et al., 2021).

Considering the studies, documents, and consulting with experts of various departments, as well as the use of existing references, there are production losses in agriculture and industry. From the stage of planting and holding to the process of sugar production, each of which can be examined in its own way. Studies show that 20-30% of the total sucrose produced by sugarcane is lost due to various reasons such as time and method of harvest, delay in processing sugar from the harvested product, poor technical knowledge and losses in the industrial sector (Saxena et al., 2010) Like other sugarcane regions in the world, machine harvesting of sugarcane in Khuzestan, Iran, is done in two ways, green and burnt. In the green method, a large amount of vegetable's impurity enters the harvester and must be separated from the stem billets. Two suction extractors are installed in the harvester that separates the trash from the sugarcane stem billets. The trashes are sucked by the primary and secondary extractors due to their lightness and are thrown out of the machine (Tweddle et al., 2021).

Shomeili (2022) reported that using acoustic sensors (audio converters) can determine the amount of losses associated with the harvester. Using an audio transducer installed behind the primary extractor blades (at the shaft connection), he was able to determine the amount of sugarcane stem losses in this area. This was done by converting the shocks to the blades as well as analyzing the output voltage of the sensors. Factors such as throwing cane shrapnel (fragments of torncane) out due to improper adjustment of the primary extractor circumference, defect in the operation of the lifting trays due to incorrect adjustment of the distance between the moving part of the lift and the fixed floor of the lift, low capacity of the initial basket and falling around it, etc. caused losses of about 5 to 24 tons per hectare. While comparing the different speed of the primary extractor (900, 1100, 1300, 1500 rpm) in the sugarcane harvester Austoft 7000, showed the optimal speed of the primary extractor for the least loss and the most suitable cleaning of the trash (vegetable impurities) with the billets should be set at 1100 rpm (Shomeili et al., 2022).

Observing the three basic conditions, i.e. mobile speed of the harvester, the speed of the primary extractor rotation and the engine rotation is very effective in changing the amount of losses from a harvester. However, the importance and role of the speed of the primary extractor rotation whose main task is to separate the trash from cane material is more than others (Viator et al., 2007). The high speed of extractor rotation causes more of the trash to be separated from the cane stem pieces but due to the high suction of the primary extractor the pieces of stems that attached to the leaves as well as the thin stems pieces of cane are sucked and thrown out of the harvester (Martins *et al*., 2017). Increasing the speed of extraction rotation to reduce only one present of plant impurities along with sugarcane billets increased shrapnel losses by more than four tons per hectare. Therefore, it is necessary to change the speed of the primary extractor rotation in proportion to the amount of trash turning into the harvester and also the degree of their adhesion to the sugarcane billets and even the diameter of the harvested stalks.This study was conducted to evaluate the feasibility of using a suitable acoustic sensor to control the quantity of sugarcane losses on the harvester Austoft 7000.

MATERIAL AND METHODS

Sugar cane harvest stage losses are mainly due to the improper performance of harvesters. Non-recyclable losses of sugarcane from different parts of the harvester may reach 18 tons per hectare. Most non-recyclable losses and sources of its creation in a sugarcane harvester are shown in Figure. 1. To monitor these losses, a research was conducted on the sugarcane harvester Austoft 7000 in Mirza Koochak Khan agro-industry, Khuzestan, Iran, during the 2014 harvest season. In the first step, a video camera was installed in the inner hood cap of the primary extractor using welding and related cabling, and then a video was taken of what was happening under the hood cap of the primary extractor.

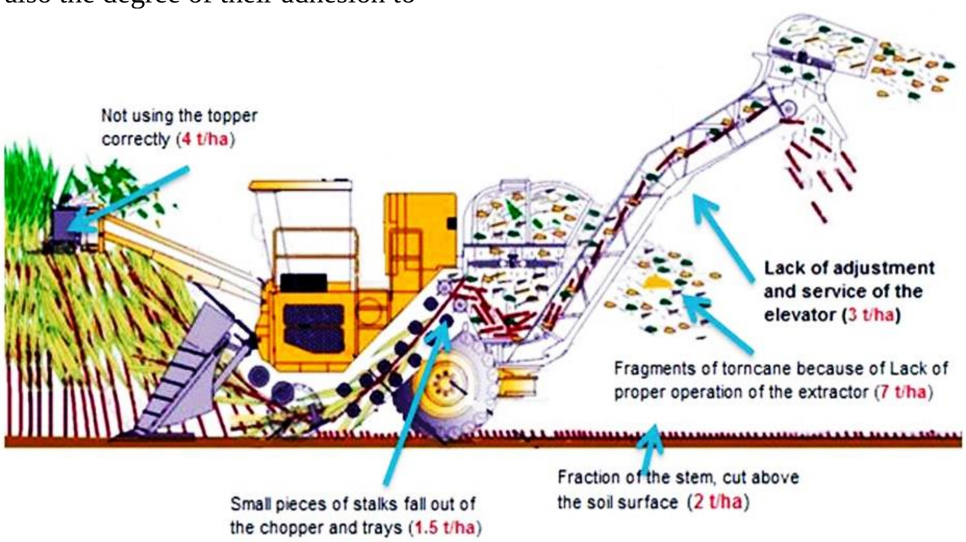

Figure 1. Most non-recyclable losses and sources of its creation in a sugarcane harvester

For recording the ambient sound inside the primary extractor, two models of capacitive microphone, one full-directional type and the other one-way microphone (cardioid) were selected. The reason for choosing capacitive models was their higher sensitivity to sound as well as good sound quality. To provide the required voltage to the two ends of the microphone capacitor, due to the high output impedance of this model, a preamplifier was needed which is usually supplied by a 9-volt battery. In this design, the required power of the microphone was provided by using a 9-volt battery (Figure. 2).

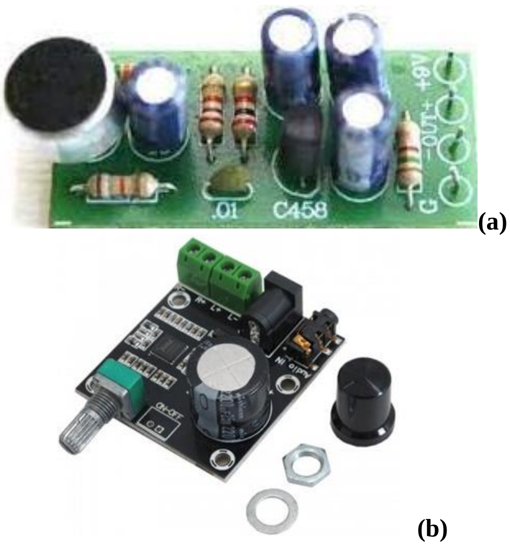

Figure 2. (a) Cardioid capacitive microphone, (b) one-way microphone

Given the working conditions of the harvester on the field and the position intended for the installation of microphones, it was necessary to think about solving the problem of capacitive microphones. Capacitive microphones are much more sensitive to wind than other models and if not properly insulated can lead to loss of quality during audio recording. To solve this problem, a compartment was designed using compact yonolit and sound insulation type and the microphone was placed completely inside this compartment. By doing this, both the vibrations caused by the protective cap of the primary extractor were less transmitted to the microphone and the external sounds such as engine noise, radiator fan, ambient wind, hydraulic motors and transport tractor, etc. were practically eliminated. To record and analyses the sound from the microphone two software “Cool Record Edit Deluxe” version 7. 9. 5 and “Audacity” version 2. 0. 2 were used. Next, according to the installation position of the camera in the primary extractor hood, a full-directional capacitive microphone was placed under the primary extractor hood and fixed using adhesive and belt expansion. Then, by connecting the audio and video transmission cables, the sound recording under the primary extractor chamber began (Figure. 3). During the harvesting operation, the microphone was damaged due to the intensity of the high air flow and the high volume of straw and the impact of the cane pieces. Therefore, in order to prevent re-damage of the microphone and also to reduce the effect of air flow on the performance of that microphone it was placed outside the protective cap of extractor. According to the images obtained from the installed camera and the studies performed it was found that the most collision of straw and cane pieces occurred when leaving the primary extractor with the upper part (roof) of the hood cap. To control the disposal condition of the trash and possible losses of cane pieces from the secondary extractor, a camera was installed on the chassis of the elevator and in front of this extractor so its images were recorded.

Figure 3. The windshield used and how to place the microphone inside it

To determine the rotation of the extractor, first one of the extractor blades was marked with a label and then the harvester operator was asked to bring the extractor circulation to working conditions in the field and finally it was recorded using a tachometer. After installing the relevant equipment and cabling inside the operator's cabin, the harvester was ready to harvesting. To begin with the harvester moved from the beginning of a farm furrow and the time was calculated using a stopwatch. This test was continued until the end of the furrow and by using a tablet and its sound recorder menu save and record the sounds received from the microphone. This test was repeated several times in a field with a yield of about 85 tons per hectare of CP1062-69 variety and the data were recorded. To reduce the disconnection of cables (due to working conditions and moving parts of the harvester), using flex tubes with two layers of metal shield and using a resistance circuit as an emergency fuse was tried to avoid any unforeseen accidents. This fuse would cut off the power to the circuit in the event of any change in amperage or voltage. By placing the power supply of the cameras in the harvester cabin and using a mobile power supply, the output current for each camera was set to 12 volts. After performing the above steps, harvester moving and damaging parts during harvesting were identified and therefore the best way for cabling was identified. Then the cables related to electricity and cameras using belt clamps and adhesive tape were placed in the desired positions. Figure 4 shows the route selected for cabling.

Figure 4. Cabling toward driver's cabin

In the next step, in order to separate the sound wavelengths created by the collision of different parts of the sugarcane with the hood cap and fan blades, a large amount of trash with 25 cm pieces of sugarcane stem was thrown into the hood and the sounds were recorded. In this way, the sound of the impact of trash or parts of the stem was separated. Then, using Audacity software, extra and low volume sounds were removed. By reducing and eliminating unwanted sounds, a clearer sound was obtained from the microphone.

RESULTS AND DISCUSSION

Multi-year field studies showed that in more than 80% of active harvesters during the early harvesting season, the primary extractor was not suitable for working due to broken hydraulic valve, lack of adjustment or lack of attention. For this reason, before the start of the harvest period the extractor speed is set at 1100 rpm by the operator which is a big mistake and this condition will remain constant until the end of the harvest period. During the harvest period, due random control of the primary extractors' rotation by a laser tachometer device it was found that most of them vary between 900 and 1300 rpm which means that there is no proper monitoring. In recent years due to mainly climatic problems for sugarcane growth in Iran, the stems have become thinner and relatively light which has increased the losses due to the throwing of cane stem pieces out by the primary extractor. Table 1 shows the results obtained from measuring the primary extractor rotation in more than 45 harvesters.

Table 1. Evaluation of measurement of harvester primary extractor rotation during harvest season in Khuzestan, Iran, 2014.

	Primary extractor rotation (rpm)		
	≥ 1200	1000-1200	≤ 1000
Ratio reviewed Harvester (%)	28	54	18

In the results obtained from the output of the audio system, as expected, the one-way capacitive microphone received clearer sounds (Figure. 5). Also, the microphone installed in the upper part of the primary extractor hood showed a greater number of collisions than the audio system installed in the side of that which was due to a more suitable position and a suitable windshield.

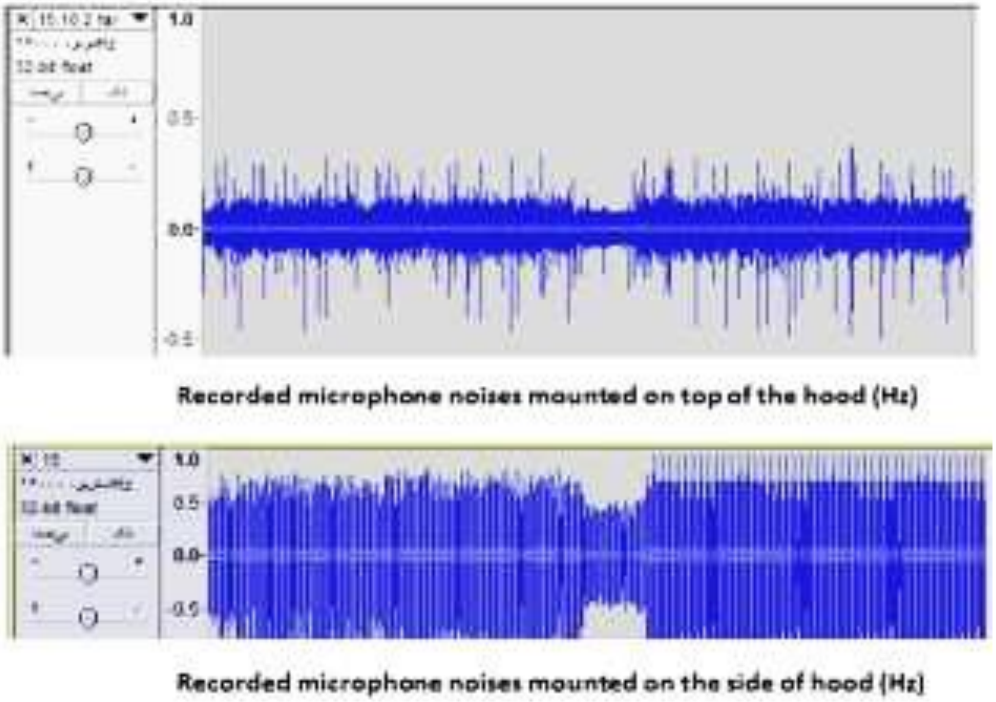

Figure 5. The difference in sound obtained from the audio system in different positions of the hood

Accordingly, only data obtained from the audio system installed above the primary extractor hood were examined. The results obtained from the analysis of recorded sounds and their comparison with the images obtained from the camera under the primary extractor showed that the sound oscillation detection system with accuracy of about 75 to 80% reveals the amount of cane losses in the primary extractor (Figure. 6)

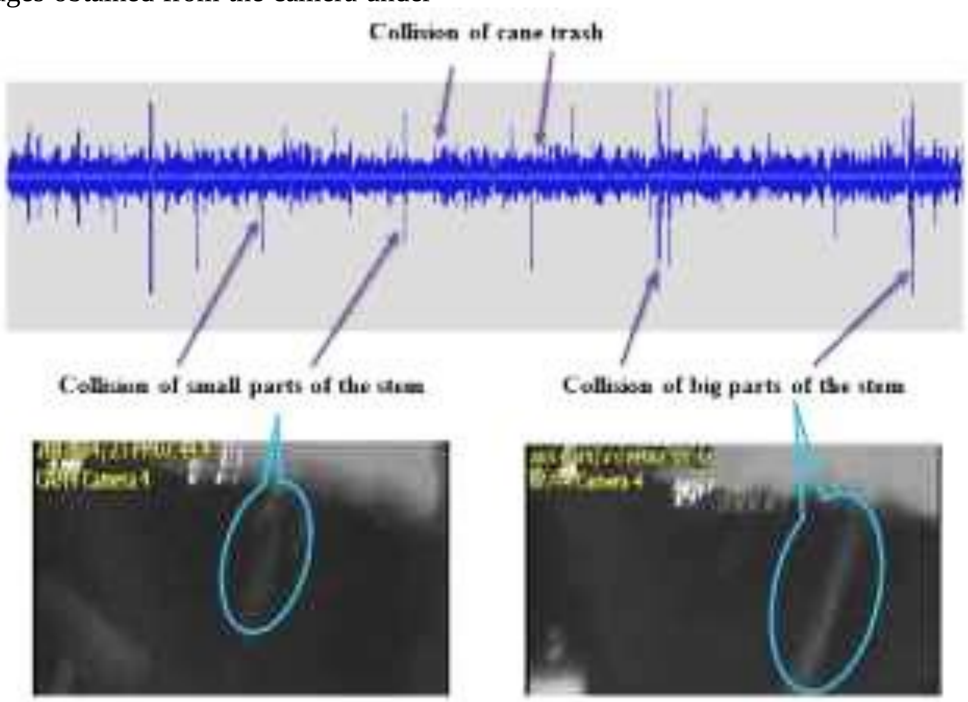

Figure 6. Results obtained from the analysis and adaptation of recorded sounds from inside the sugarcane harvester primary extractor hood chamber and related camera videos

Figure 7 shows a comparison of losses amount in the two rotations of 1100 and 1200 rpm from sugarcane harvester primary extractor. As you can see from the picture, the loss rate at 1200 rpm is about 1.5 times higher than the reed loss at 1100 rpm. In (Martins et al., 2017) study, different amounts of sugarcane losses were reported in machine harvesting due to improper harvester performance, especially at the extractor rotation while in the study of (Ramos et al., 2014) no significant difference was observed in the rate of cane losses by changing the functions of sugarcane harvesters. These different results are affected by various factors some of which are related to the health of the harvester and some to the field conditions considered for harvest. In addition to these two factors the effects of climatic conditions can also be considered as a sub-factor.

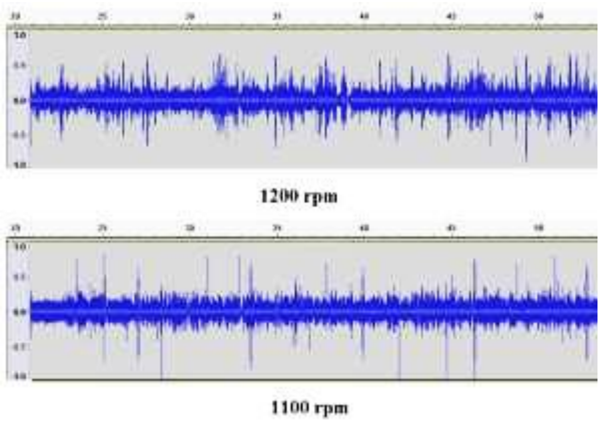

Figure 7. Analysis of recorded sounds from the primary extractor at 1100 and 1200 rpm

The primary extractor rotation affected both the quantity and quality of sugarcane lost from this section of harvester (Figure 7). The rate of cane losses at 1100 rpm was more in the form of pieces with a length of about 15 to 25 cm while at 1200 rpm losses were more in the form of pieces with a length of less than 15 cm. (Viator et al., 2007; Whiteing et al., 2001). Also pointed same results losses from primary extractor of sugarcane harvester. Increasing the extractor fan rotation too much based on the condition of the ready-to-harvest crop on the field will not only increase the losses but also make them smaller and often invisible. He speeds of the harvester is one of the factors that change the efficiency of the extractors by changing the amount of plant material entering the harvester, which affects the amount of losses. But the losses are reduced. However, raising the work speed will provide gain in operational and economic performances, although it is important to consider whether sugarcane losses will be detrimental to the Mill income (SANTOS et al., 2015).

CONCLUSIONS

This investigation revealed that the use of a sound monitoring sensor that has the ability to distinguish between different types of sounds can help to determine the amount of losses from the sensitive part of the sugarcane harvester, i.e. the primary extractor. By integrating this audio sensor into a software kit, it is possible to automatically adjust the primary extractor rotation to the proper speed. Therefore, crop losses are reduced to a minimum and this was the subject of the first phase of this study. It is recommended that in the continuation of this work such audio sensors and its monitoring software be prepared as a kit and tested on a large scale on several devices.

REFERENCES

Santos, N. B., Fernandes, H. C., & Júnior, C. D. G. (2015). Economic impact of sugarcane (Saccharum spp.) loss in mechanical harvesting. *Científica*, *43*(1), 16-21.

Kosum, K., & Bun-art, S. (2020). The Losses of Sugarcane Harvested from a Sugarcane Harvester. *Suranaree Journal of Science & Technology*, *27*(1), 1-9.

Maleki, H., & Jamshidi, A. (2011). Forecast model of sugar loss due to mechanical harvesting of the sugarcane crop. *Australian Journal of Basic and Applied Sciences*, *5*(12), 1190-1194.

Martins, M. B., Testa, J. V. P., Drudi, F. S., Sandi, J., & Lanças, K. P. (2017). Losses in the mechanized harvest of sugarcane as a function of working speed and rotation of the primary extractor. *Científica*, *45*(3), 218-222.

Pallathadka, H., Mustafa, M., Sanchez, D. T., Sajja, G. S., Gour, S., & Naved, M. (2023). Impact of machine learning on management, healthcare and agriculture. *Materials Today: Proceedings*, *80*, 2803-2806.

Ramos, C. R. G., Lanças, K. P., Lyra, G., & Millani, T. M. (2014). Qualidade da colheita mecanizada de cana-de-açúcar em função da velocidade de deslocamento e rotação do motor da colhedora. *Revista Energia na Agricultura*, *29*(2), 87-94.

Saxena, P., Srivastava, R., & Sharma, M. (2010). Impact of cut to crush delay and bio-chemical changes in sugarcane. *Australian Journal of Crop Science*, *4*(9), 692-699.

Shomeili, M., Ahmadi, S., Asodar, M. A., & Jamshidi, A. R. (2022). Evaluation of an intelligent device for identifying cane losses from sugarcane harvester primary extractor. *Journal of Environmental Treatment Techniques*, *10*(2), 143-148.

Tweddle, P., Lyne, P., Van Antwerpen, R., & Lagerwall, G. (2021). A review and synthesis of sugarcane losses attributed to infield traffic. *Advances in Agronomy*, *166*, 197-250.

Viator, R. P., Richard, E. P., Viator, B. J., Jackson, W., Waguespack, H. L., & Birkett, H. S. (2007). Sugarcane chopper harvester extractor fan and ground speed effects on yield and quality. *Applied engineering in agriculture*, *23*(1), 31-34.

Whiteing, C., Norris, C., & Paton, D. (2001). Extraneous matter versus cane loss: finding a balance in chopper harvestered green cane. International Society of Sugar Cane Technologists. Proceedings of the XXIV Congress, Brisbane, Australia, 17-21 September 2001. Volume 2,