Research article

The Optimum Speed Investigation of the CASE Harvester Cleaning Fan for KK3 Sugarcane

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Abstract During sugarcane harvesting process on fields, there were sugarcane losses occurred in the process such as blown-out loss from a primary extractor fan used to clean leaves out of the sugarcane, loss from conveyers and from high cutting by a base cutter. Different species of sugarcane (*Saccharum officinarum* L.) contained different trunk and leaf sizes, different cleaning fan speeds should be considered. If the losses are reduced, the better process can be obtained, and farmers get more income from more products and less loss. This work focused on finding the proper operating speeds of the primary extractor fan equipped in the sugarcane harvester; A8000/8800 model CASE IH trademark, to harvest the Khon Kaen 3 (KK 3) sugarcane (*S. officinarum* L.) in the minimum contamination and by the maximum flawed sugarcane sticks less than 2%. The harvester manufacturer has recommended the fan speed at 800 rpm as the suggested speed. The experimental investigations in five different operating speeds; 700, 800, 900, 1000 and 1100 rpm, of the fan were performed at the sugarcane field in Saybouly District, Kenghat Village, Lao PDR. Ten different sampling points were specified to check contamination; sand, leaves and flawed sugarcane sticks, along 400-meter-long plots with 1.65-meter plot offset. Each sampling point was in a 10-meter-square area. The reported values were average values obtained from all points in three repeating examinations. We found that the minimum contamination was 7.26% and the flawed sugarcane was 1.95% when the fan speed at 700 rpm. The maximum contamination was at the highest speed. Therefore, the fan speed at 700 rpm was used as the new operating speed for the harvester in the KK 3 sugarcane harvesting process to reduce the losses.

Keywords sugarcane, sugarcane harvester, primary extractor fan

INTRODUCTION

Nowadays, the sugarcane and sugar industries have been experiencing a shortage of labor in agriculture and the cost of sugarcane harvesting is clearly increased. Thai society is entering the ageing society and the government policy has promoted increasing the minimum wage. Consequently, young workers are more interested in working in factories and service sectors than in agricultural sectors. It is anticipated that the labor shortage is going to occur in Thai and other sugar industries.

A Chopper sugarcane harvester is one of popular sugarcane harvesters and it has been used to harvest sugarcane to replace human workers and to reduce the harvesting cost. Thai public and private groups have imported sugarcane harvesters from overseas and have researched to develop sugarcane harvesters in Thailand. However, sugarcane harvesters have still been imported from abroad. One of disadvantages found from using the harvesters is contamination during the harvesting process that affects the sugar production directly. The contamination can cause sugarcane fractures which fall out the cutter and the harvester cannot pick up from harvested fields.

Sugarcane losses during the sugarcane harvesting have been reported by Ridge et al. (1993) as following; 1) the loss from two cleaning fans blowing small sugarcane sticks away; the large one equipped on the top of the sugarcane collecting basket and the small one equipped at the end of the conveyor, 2) the loss from the conveyor because gaps on the conveyor were bigger than the sticks, 3) the loss from human errors such as workers have low skills causing high sugarcane cutting and unsuitable sugarcane-row preparation and 4) the loss during transportations such as sugarcane transportation from fields on trucks and during transportation between the fields and factories on the trucks without any covers.

The sugarcane harvesters in Thailand, especially in the sugarcane industry, can be divided into two categories; the Whole Stick Sugarcane Harvester and the Chopper Sugarcane Harvester. The Whole Stick Sugarcane Harvester (Opanukul et al., 2012), which is attached to a large tractor as in Fig. 1(a), can cut sugarcane into whole trunks and stack the trunks in piles next to sugarcane rows, then a sugarcane loader grips the trunks onto transporting trucks to transport the sugarcane to the sugar factories. Performances of these harvesters are in 50 to 80 tons per day. The Chopper Sugarcane Harvester (Opanukul et al., 2012), as shown in Fig. 1(b), can cut the sugarcane by the base cutter into trunks, convey the trunks on the conveyor set to the chopper set, chop the trunks into small sticks and transport the sticks by the elevator set on transporting trucks to the factories. Performances of the latter harvesters are in 100 to 300 tons per day.

(a) **(b)**

Fig. 1 (a) The whole stick and (b) the chopper sugarcane harvesters (Opanukul et al., 2012)

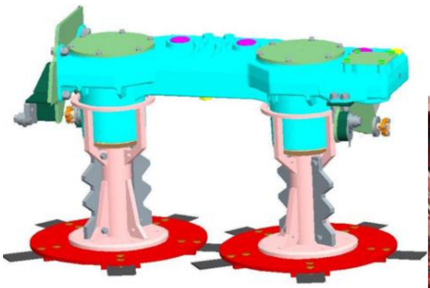

Fig. 2 Base cutter blade (Ma et al., 2014)

Fig. 3 Primary extractor fan (Ma et al., 2014)

Ma et al. (2014) introduced research and development of sugarcane harvest technology. There were 2 popular ways in sugarcane harvesting; the harvesting with a pre-burning process before a cutting process and the fresh harvesting without any pre-burning processes. Since the burning process produce greenhouse gases, this work also tried to raise social awareness on the greenhouse gas effects and impacts on the environment. This work presented mechanics and geometry information such as the speed of the Base cutter blade (Fig. 2), the cutting angle and inclination of the bottom-cutter blade and the shape of the blade influencing the cutting process and quality. They showed that there were two interesting techniques could be applied to improve harvesting yields; to adjust the rotation speed of the primary extractor fan (Fig. 3) and to control the height of the cutter blade to cut sugarcane at the lowest part of the sugarcane. They also noted that the research and development of the harvester components, as well as, improving the cutting and conveying mechanisms, could reduce losses and contamination in the sugarcane harvesting.

Manhaes et al. (2014) presented visible losses in harvesting with the sugarcane cutter; Case IH Baguette Model A4000. This research was conducted with the RB7515 sugarcane without any pre-burning processes in the daytime. Sugarcane row lengths, soil moisture contents, soil types, sugarcane ages and harvesting yields per hectare were collected in the research and to evaluate the visible losses from the cutter. The research information was randomly collected from 350-m field length while 8 samples were taken in every 50 m in width and length of 10x2 m is 20 square meter. This research reported that sugarcane was cut and broken into small pieces by the knife set of the cutters and these sugarcane pieces were sucked out by the large cleaning fan along with sugarcane leaves causing losses. The visual losses were reported as the average loss was at 1.85 tons per hectare or 3.4% of the total samples while the average percentages of the loss suggested by Benedini et al. (2011) were from 2.5 to 4.5%. The results from this work showed that preparation of the sugarcane fields which were longer than 350 m with 1.5-m row spacing enhanced the good production yields from using the harvester because no harvester turn was required, and the harvester wheels did not press on the sugarcane base.

The loss of sugarcane harvested from the sugarcane cutter resulted from the cutting speed and the speed of the cleaning fan was reported by Martins et al. (2017). This work evaluated the losses and contaminants in sugarcane harvesting of the cutter; the CASE IH 8800 sugarcane cutter, from three cutter speeds; 3, 5 and 7 km/h, and two rotation speeds of the fan set; 700 (R1) and 1,000 (R2) rpm. The Copersugar Technology Center 15 (CTC 15) sugarcane was chosen to harvest without any pre-burning processes in straight fields with 1.5-m row spacing and the average harvesting yield was 92.5 tons per hectare. Results of the work showed that the contamination percentages obtained from the large cleaning fan at R2 was in the range of 4 to 6% while the percentages obtained from the fan at R1 was more than 7%. The sugarcane fracture percentages blown from the large cleaning fan was less than 2.5%. This work concluded that the higher the cleaning fan speeds showed the lower the contamination while the harvester speeds did not affect the contamination.

OBJECTIVES

This research was carried out to investigate losses from the sugarcane fractures left on the fields and from the contamination sucked from the large cleaning fan of the harvester. The latter loss occurred from the fan was analyzed to determine the optimum fan speed in the sugarcane harvesting, as well as, to provide information for sugarcane farmers who have their own sugarcane harvesters. This research aimed to find the suitable speed of the big cleaning fan equipped in the harvester; CASE IH sugarcane cutting machine model A8000/8800. The suitable speed could provide the lowest loss in the Khon Kaen 3 (KK3) harvesting from 5 different speeds; 700, 800, 900, 1000 and 1100 rpm.

METHODOLOGY

1. Analyzing KK3 sugarcane age information from a database of Mitr Lao Sugar Co., Ltd., to find ages of sugarcanes which were harvested.
2. Selecting the proper experimental field which provided 10 tons per 0.16 hectare or ha (Fig. 4).
3. Selecting the harvester suggested by Mitr Phol group and on duty in the selected field from Step 2.
4. Adjusting the speed of the big cleaning fan equipped in the harvester to 5 investigated speeds; 700, 800, 900, 1,000 and 1,100 rpm.
5. Collecting data at each speed of the big cleaning fan; a distance between collecting points, weights and types of residue rejected from the fan and weights of usable sugarcane sticks

(yield). Types of the residue, which was rejected from the fan, consisted of sugarcane scraps and waste. An area of the collecting point was 5x2 square meters, a canvas sheet (Fig. 5) was selected and laid to collect the samples.

6. Analyzing the sugarcane loss by calculating following equations applied by Mitr Lao Sugar Co., Ltd. (2018). This work focused on the loss from the primary (large) cleaning fan blowing sugarcane scraps away.

The sugarcane scrap loss in kilogram per 0.16 hectare (0.16 ha equals to 1 Rai in Thai unit);

$$Sugarcane\ scrap\ loss = \frac{Average\ sugarcane\ weight\ (kg)\ x\ sugar\ cane\ length\ per\ hectare\ (m)}{Sugar\ cane\ sampling\ length\ (m)} \tag{1}$$

The percentage of the sugarcane scraps blown out by the primary cleaning fan;

$$Blown-out\ percentage = \frac{Loss\ of\ sugarcane\ (kg\ /\ 0.16\ ha)}{1,000}\ x\ \frac{100}{Productivity\ (ton\ /\ 0.16\ ha)} \tag{2}$$

The percentage of waste blown out by the primary cleaning fan;

$$Waste\ blown-out\ percentage = \frac{Impurities\ (kg\ /\ 0.16\ ha)}{1,000}\ x\ \frac{100}{Productivity\ (ton\ /\ 0.16\ ha)} \tag{3}$$

Fig. 4 One of sugarcane fields

Fig. 5 Sugarcane sampling

RESULTS AND DISCUSSION

From the database of Mitr Lao Sugar Co., Ltd., the sugarcanes aged from 10 to 14 months were harvested because they provided an average yield of 10.282 tons per 0.16 hectare. The proper experimental field was at 111 Unit 10, Kenghet Village, Xaybouly District, Savannakhet Province, Lao PDR. The sugarcane field was prepared to have 1.65-m row spacing. the Chopper harvester; CASE IH sugarcane cutting machine model A8000/8800 with 350 hp, was selected as the experimental harvester. The harvester speeds could vary from 5 to 6 km/h, the harvester was set to have the average speed at 5.5 km/h. From the harvester information, the minimum speed of the fan was 700 rpm. In this work, 5 different speeds were investigated and found that the higher the speeds provided the heavier the residue as shown in Table 1. The residue consisted of waste (sand and leaves) and broken sugarcane sticks.

The distance between collecting points was 10 m. Weights and types of the residue rejected from the fan were shown on Table 1, leaves were heavier than sand in every fan speed. The average weights of the usable sugarcane sticks which could be calculated as the yield was at 10.282 tons per 0.16 hectare. The calculated results were shown in Figs. 6 and 7. The minimum and maximum small-sugarcane-stick losses in kilogram per 0.16 hectare were 200.37 kilogram at 700 rpm of the cleaning fan and 372.97 kilograms per 0.16 hectare at 1,100 rpm of the cleaning fan, respectively. The minimum and maximum percentages of the small sugarcane scraps blown out by the primary cleaning fan were 1.95% and 3.62%, respectively. The minimum and maximum percentages of waste blown out by the primary cleaning fan were 7.26% and 11.21%, respectively.

Since the harvester manufacturer recommended users to set the fan speed; the suggested fan speed, at 800 rpm. We observed from Fig. 7 that the higher the fan speeds the more the residue weights. The KK3 sugarcane has its own characters, therefore, we should find the proper fan speed to clean the KK3 sugarcane sticks before they are sent to next processes. Therefore, we found the proper fan speed to clean the KK3 sticks at 700 rpm because, at this speed, the harvester provided the best percentage of the blown-out scraps compared with the total weight at 21.16%, the least amount of the scrap. Moreover, the higher the fan speeds, the harvester consumed more fuel.

Table 1 Collected data from 5 different speeds and their statistical information; Average (Avg.) and Standard Deviation (SD) values

Fan speed (rpm)	Avg. sand weight (kg/0.16 ha) (1)	SD sand weight (2)	Avg. leaf weight (kg/0.16 ha) (3)	SD leaf weight (4)	Avg. sugarcane scrap weight (kg/0.16 ha) (5)	SD sugarcane scrap weight (6)	Avg. total weight (kg/0.16 ha) (7)	Scrap per total weight (%) (5) / (7)
700	233.29	0.11	513.02	0.09	200.31	0.10	946.61	21.16
800	271.60	0.08	578.61	0.13	228.92	0.55	1,079.13	21.21
900	303.61	0.44	626.14	0.98	253.17	0.10	1,182.92	21.40
1,000	331.26	0.42	671.24	0.68	276.94	0.45	1,279.43	21.65
1,100	356.48	0.37	796.37	1.03	372.97	0.57	1,525.81	24.44

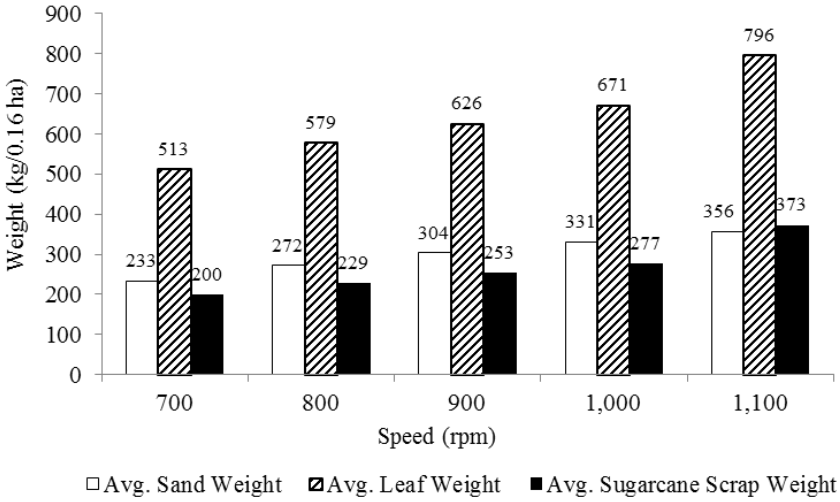

Fig. 6 Average weights of the waste and scrap

CONCLUSIONS

The sugarcane scraps blown out from the primary (big) cleaning fan of the sugarcane harvester can be considered as one of the main losses in the sugarcane and sugar industries. This research focused on the sugarcane scrap loss from the Chopper harvester; CASE IH sugarcane cutting machine model A8000/8800 with 350 hp. The experimental field was in Lao PDR and the KK3 sugarcanes were planted, the fields which provided an average of 10 tons per 0.16 hectare was chosen. Five different speeds of the primary cleaning fan were tested; 700, 800, 900, 1,000 and 1,100 rpm, the blown-out residue was collected 10 positions along the field lengths. Then, the residue was separated into sand, leaves and sugar scraps, weight of each part was collected and calculated in the literature equations. When we considered the scrap weights divided with the whole residue weights as the percentages of the scrap compared with the total weights, we found that the scrap percentages obtained from the fan speeds at 700, 800, 900 and 1,000 rpm were about 21. If we considered fuel consumption values among these four percentages, the fan speed at 700 rpm consumed the least fuel with the minimum scrap percentage. The current research information suggested that the primary fan of the CASE IH sugarcane cutting machine model A8000/8800 should be set speed at 700 rpm to clean the unwanted parts out from the KK3 sugarcane sticks harvested from the fields.

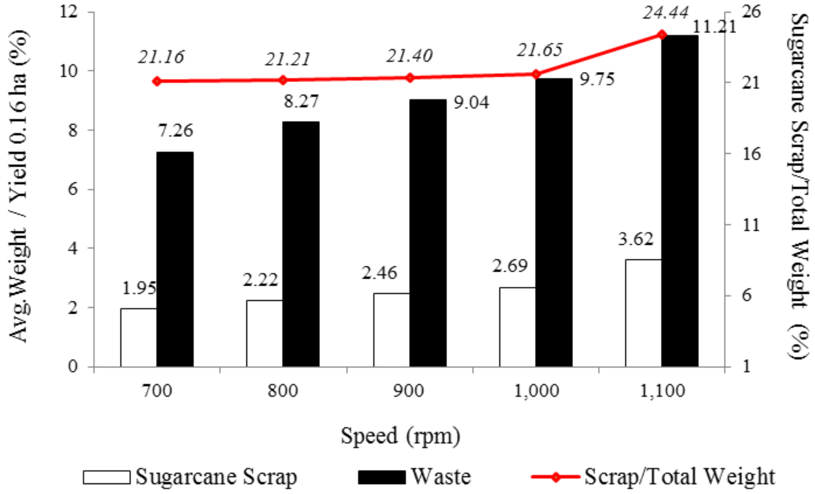

Fig. 7 Percentages of the scrap and waste weights compared with the yield weights (the left axis) and percentages of the scrap compared with the total weights (the right axis)

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