EFFECTS OF DIFFERENT BALE DENSITY SETTING ON COLLECTION CAPACITY OF IMPROVED MINI ROUND BALER

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ABSTRACT

Rice straw is a by-product generated during harvesting process. In 2022, around 2.8 million metric tonnes of rice straw were generated at 637,955,9 hectares of rice planted area. Currently, open burning of the rice straw is widely practised by the farmers because it is easy and cheaper. A proper management of the rice straw is necessary to promote healthier approach and fulfilling demand for various applications. Utilization of mini baler is less preferred by service provider rather than big commercial baler in collecting the rice straw because of its collection capacity. Therefore, improvement on the existing method in collection of the rice straw is required to enhance its productivity. Evaluation of the improved baler is conducted to determine its performance and capability at the speed of 1.6 km/hour and different setting of bale density. Collection of the rice straw is conducted with and without slashing the stubble and producing the bale with diameter and length of 50cm and 70cm respectively. Different setting of bale density has affected the results of collecting time, weight of bale and collecting capacity. The collecting time for grade A bale is faster than grade B bale meanwhile the weight of bale for grade B bale is higher than grade A bale. Result of corelation analysis has indicated strong relationship between collecting time and weight of bale based on the result of P-value which is less than 0.05. The range of collection capacity for grade A and grade B of the baler is 243.3 kg/hour to 274.1 kg/hour and 310.5 kg/hour to 343.2 kg/hour respectively. Factor of rice straw distribution and its physical properties such as moisture content and density has influenced the value of machine capacity.

Keywords: Rice Straw, Field Mechanization, Mini Round Baler, Collecting Capacity, Bale Density

INTRODUCTION

Rice straw was generated during harvesting process of rice. Nowadays, combine harvester is commonly used to harvest the rice and rice straw will be left behind on the stubble. In 2022, total number of rice planted area in Malaysia was 637,955 ha and able to produce 2,281,736MT of rice (Booklet Statistik Tanaman, 2023). Yield of total rice straw generated was varies depending to variety and cutting height of the straw during crop harvesting. A study conducted by Martin G. et.al. (2020) had disclosed the straw to grain ratio was 0.5:1 for the cutting height of remained stubble at 40 cm. Javier Matias et al. (2019) also conducted a study on the straw to grain ratio which is 1:1 at the cutting height of 25 cm above the ground by using rice harvester. However, in Malaysia, the ratio of grain to straw as reported by MADA (2010) was 0.45:0.55. In this ratio, the amount of straw was an accumulation of straw and stubble. The stubble was slashed prior to straw collection. Based on this ratio, quantity of rice straw that available in 2022 is approximate 2.8 million MT.

Currently, there are several approaches being implemented by farmers to manage the rice straw such as open burning, incorporation in the field and off-field usage (Aditya S. et. al., 2022). Nevertheless, the most famous method by farmers is open burning to clear it from the field prior to starting of next planting season. This method is easy & cheaper, traditionally practiced, able to eliminate disease & pest and contribute to soil fertilization (Rosmiza M.Z. et al., 2012). Burning of rice straw may contributes to bad effect on environment such as air pollution that led to deterioration of the local community health and safety.

Besides, the rice straw also collected during dry soil condition only for various application by using a trailed type commercial baler that attached to a tractor. The baler was commonly produced round baled straw with the size of 1 m diameter and 1.2 m length with the weight around 150 kg. The bale straw was ejected from the machine on the field and be collected using a grabber. This practice has been conducted in several location such as MADA and Sekinchan area. Rice straw is a renewable resource and potentially can be used for various application such as lifestock feed, compost, craft paper making, mushroom growth medium, energy production, nursery mat and others product development (Rosmiza M.Z. et. al., 2015 and Lakhvir S. and Balraj S.B., 2021).

However, collection of the rice straw by using small baler less considered by the service provider due to low production capacity as compared to the commercial baler. In order to improve the operation of baling process using small baler, it was modified and evaluated at different setting of bale density. The baling and infield transporting of bale were integrated in order to improve and simplify the operation. Usage of small baler might benefit farmers and enhance the socioeconomic of local community towards sustainability of rice industry.

MATERIALS AND METHODS

EXPERIMENTAL SITE

The experiment was conducted at MARDI Parit where was planted with MARDI SIRAJ 297 rice variety and harvested using a combine harvester. The rice straw and stubble were kept as they were after harvesting operation to produce grade A by collecting the rice straw on the stubble only. Meanwhile for grade B bale, the rice straw and stubble were collected after cutting using rotary slasher. Moisture content of the rice straw and stubble was measured and recorded.

IMPROVED MINI ROUND BALER

The Star mini round baler (MRB0855N) was modified by integrating with carrier mechanism to improve the baling operation. The carrier mechanism was capable to carry 10 pieces of bale prior to unloaded into lorry. The baler was attached to 3-points link of a tractor and adjustment of the top link was conducted to enable the machine working properly.

MACHINE EVALUATION

The baler was setup at three level of density namely light, medium and heavy to produce grade A and B bales. The machine was operated to produce 10 pieces of bale for each level of density. The baling operation was conducted at constant speed of tractor which is 1.6 km/hour but controlled by the operator based on condition of the rice straw. Size of the bale produced was 50 cm diameter and 70 cm width. The feeding time and weight of bales produced were measured and recorded. Collection capacity of the baler was calculated based on the following formula to determine performance of the machine.

$$Collection\ Capacity\ (kg/hr) = \frac{Total\ weight\ of\ bale\ (kg)}{Total\ duration\ of\ operation\ (hr)}$$

DATA ANALYSIS

Data of collecting time, weight of bale and collection capacity were analysed to observe their effect at different setting of bale density. Value of mean and its standard deviation were calculated and interpreted to verify the pattern. The comparison between grade A and B bales was made. Besides, correlation analysis between collecting time and weight of bale was carried out by using Minitab 16 software to identify its relationship behaviour.

RESULTS AND DISCUSSION

Operation of the mini round baler was conducted by attaching to a 90 HP tractor based on the following setup shown in Table 1 to produce bale with grade A and B. The tractor operated by a driver and assisted by an operator to handle the bale after discharged from the machine.

Table 1: Setup of tractor and improved mini round baler

Engine speed (RPM)	PTO speed (RPM)	Collector speed (RPM)	Roller speed (RPM)
2,000	485	100	200

The baling operation was conducted at moisture content of rice straw and rice stubble around 15% to 25%. Normally the operation was started at 11.00 am during normal sunny day. Results of feeding time and weight of bales displayed in Table 2 and Table 3.

Table 2: Results of collecting time for each bale at different grade and density

Item	Collecting time (s)					
	Grade A			Grade B		
	LD	MD	HD	LD	MD	HD
Average (AVG)	112	194	258	125	289	294
Standard Deviation (STDEV)	50	55	47	28	70	45

Note: LD = Light density, MD = Medium density, HD = Heavy density

Table 3: Results of weight for each bale at different grade and density

Item	Weight of bale (kg)					
	Grade A			Grade B		
	LD	MD	HD	LD	MD	HD
Average (AVG)	7.4	14.0	17.1	11.5	24.2	26.7
Standard Deviation (STDEV)	0.8	1.1	1.0	0.7	2.6	1.2

Note: LD = Light density, MD = Medium density, HD = Heavy density

In general, results of the collecting time have displayed an upward trend by increasing density of the bales. More time required to compact the rice straw and stubble at heavier preset density of bale. Findings reported by Senthilkumar T. et al (2016) also indicated the same trend of collecting time to produce a bale at higher size. Collecting time for each density and grade of bale is relatively different. Result of heavy density of Grade A bale and light density of grade B bale have displayed lower standard deviation compared to others. Uniformity of the rice straw and stubble quantity on the working lane has affected the results of collecting time.

Results of weight for each bale also indicated the same trend likes collecting time. Bale with lower preset density had displayed less amount of weight for both grade of bale. At heavy density of bale, the rice straw and stubble were compressed more to achieve the preset density. Grade A bale indicated less variation of the results for each preset density as compared to grade B bale. Physical properties of the rice straw and stubble such as moisture content had influenced the result of weight for each bale. The range of density for grade A and grade B bales were 54.0 kg/m^3 ~ 124.0 kg/m^3 and 83.3 kg/m^3 ~ 194.5 kg/m^3 respectively. Based on these results, the compaction density was considered as low because less than 300 kg/m^3 (Carlito B. et al., 2020).

Based on the result of collecting time and weight of bale, collecting capacity of the improved mini round baler was calculated and indicated as in Table 4. The highest capacity for grade A and B is 274.1 kg/hr and 343.2 kg/hr respectively. However, data for heavy density of grade A and medium density of grade B displayed more consistent data because of less variation for average data as noted by figure of standard deviation. Uniformity of rice straw and stubble along the collecting path has contributed to the results. At constant speed of tractor, those area with less amount of rice straw and stubble requires more time to complete a bale according to preset density on the machine.

Table 4: Results of collecting capacity at different grade and density

Item	Collecting capacity (kg/hr)					
	Grade A			Grade B		
	LD	MD	HD	LD	MD	HD
Average (AVG)	273.8	274.1	243.3	343.2	310.5	334.2
Standard Deviation (STDEV)	96.7	65.4	31.5	64.6	46.0	52.9

Note: LD = Light density, MD = Medium density, HD = Heavy density

Table 5: Results of correlation analysis between collecting time and weight of bale for each bale density

Specification of bale	Pearson correlation coefficient	P-value
Light Density, Grade A	0.691	0.027
Light Density, Grade B	0.632	0.05
Medium Density, Grade A	0.453	0.189*
Medium Density, Grade B	0.753	0.012
Heavy Density, Grade A	0.801	0.005
Heavy Density, Grade B	-0.048	0.896*

* Correlation between collecting time and weight of bale not statistically significant

Analysis of correlation between collecting time and weight of bale have displayed correlation between each other based on the result of Pearson correlation coefficient and p-value as indicated in Table 5. Most of the results have indicated strong correlation based on the value of Pearson correlation coefficient and P-value. However, results of medium density grade A and heavy density grade B has not significantly different probably due to poor uniformity of the rice straw on the collecting path and inconsistent of tractor's travelling speed during baling operation. Adjustment on the speed of tractor done by operator to ensure smooth operation of baling process according to condition of the rice straw on collecting path.

CONCLUSION

Collection of rice straw for variuous applications has benefited farmers and promote healthier environment. Different setting of bale density at the baler have affected the results of collecting time, weight of bale and collecting capacity. In general, the results of collecting time and weight of bale have indicated an upward trend whenever the setting of bale density increased. Both measured parameters have shown strong relationship among each others by interpreting the value of Pearson correlation and P-value from correlation analysis. Meanwhile, the result of collecting capacity for grade B bale has displayed higher value than grade A bale because of rice straw properties such as mouisture content and material density. The improved mini round baler is capable to bale rice straw upto 274.1 kg/hr and 343.2 kg/hr for grade A and grade B bale respectively.

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