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Effect of Grain Moisture Content on Soybean Thershing Performance

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Abstract

This study aimed at investigating the effect of grain moisture content on soybean thershing performance. The result would be applied in developing a soybean combine harvester to be installed with a small tractor. The axial-flow soybean threshing unit is composed of a rotor of 0.48 mm diameter and 0.70 m length, peg tooth clearance (PC) of 41.4 mm, concave clearance (CC) of 20 mm, guide vane inclination (GI) of 80°, rotor speed (RS) of 10 m/s and feed rate (FR) of 150 kg/h. The investigated factors included grain moisture content (MC). The completely randomized design (CRD) experiment was planned by setting the soybean moisture contents at three levels, i.e., 14.94, 23.55 and 36.04%wb. The experiment demonstrated that the MC significantly affected the threshing efficiency, total loss, and percentage of breakage. The axial-flow soybean threshing unit is recommended for soybean moisture content of not over 15%wb.

Keywords: Soybean threshing, Axial-flow Thresher, Grain Moisture content

1 Introduction

Thai farmers usually plant their soybean in the dry season in paddy fields after rice harvest and at the end of the rainy season in crop fields. In general, the harvested soybeans are 95-100 days at the harvest time. Roughly 3-4 workers work at a capacity of 0.02 ha/h. including baling the harvest produce. The soybean bales are left in the plots for 3-7 days so that their grain moisture content is reduced to roughly 13-15% before being threshed by a rice thresher (Vejasit, 1991). The major problem found in harvest and threshing was a shortage of labor, which also cost higher than other types of production. One solution is to use an appropriate farm machine, particularly one that can harvest and thresh at the same time. However, this kind of machine should not result in loss and damage of the produce at a greater rate than is acceptable among the farmers, the wage rate should not be higher than the conventional method, and the operation should not be complicated (Chamsing, 1996). The popular thresher hired out is a high-capacity large thresher, i.e., 1.83 m (6 ft). Soybean threshing, in general, does not take into account loss and damage from the work. The average rotor revolution used is 600 rpm (Rojanasaroj et al., 1989 and Sirisomboon, 1992). The high revolution speed of the rotor means violence that in turn leads to loss and damage of soybean grains, including unthreshed loss and separating loss (Rojanasaroj et al., 1989) Amount of loss is observable from grain breakage or crack. In addition, threshing soybean using threshers with different principles may cause different characteristics of damage to grains. Soybean with high moisture content resists threshing strength better than soybean with low moisture content. However, weakness could occur inside the grain and hence sprouting percentage could be reduced (Chinsuwan et al, 1990). There are some limitations in the use of a rice combine harvester for soybean: there is a need for consistent condition of the plot, loss usually occurs owing to incomplete harvest, soil is mixed in the produce because the first pod is close to the soil and the combine harvester does not cut closer to the soil, weeds are clogged in the threshing system, and percentages of loss and breakage after harvest are over 7.9 and 17.4%, respectively (Thongsri et al., 2015). Moreover, the diversity of soybean plots makes it inappropriate to use large machines. All of these problems are required to be solved. Nowadays, more farmers turn to use small tractors, and many of them own a tractor as the initial power of transporting and trailing various farm labor-saving devices. Therefore, there are more needs to develop trailer devices or certain installments for more use and benefits from farm machinery. Nakqoue (1994) said that a small soybean combine harvester suitable to the plantation is not very expensive, and small and potential farmers are able to purchase one from the producer in order to contract soybean harvest in their locality. This is one way to reduce soybean production cost. The machine is efficient in terms of its performance and hence product loss is lowered. In fact, soybean production has faced a problem in harvesting and threshing because it needs human labor. This problem can now be solved by installing a farm tractor with a soybean combine harvester, which has been designed and manufactured for a 22 HP farm tractor of a 1400 width x 5,000 length x 2,200 height mm size. This device comprises a reaper head, a conveyor, a thresher, a cleaning unit, and a 4 Ft (1.2 m) axial flow rotor. The plantation experiment performed showed that the machine has a capacity of 0.0944 ha/h, with an efficiency of 42.37%. The percentage of loss is lowest when operating at the reel index and cutter speeds of 1.0 and 0.5 m/s, respectively (Chirattiyangkur et al. 2006)

A. Vejasit et al. (2004) studied the impact of operations on the performance of an axial flow rice combine harvester having a teethed rotor designed for soybean. The threshing efficiency was found to be at 98-100%. Grain breakage and grain loss were less than 1.0 and 1.5%, respectively, at the rotor speed of 600 to 700 rpm, the feed rate of 540-720 kg/h and grain moisture content of 14.34-22.77%wb. The maximum power used was 2.29 kWat the grain moisture content of 32.88%wb and the rotor speed of 700 rpm. For higher threshing performance at the grain moisture content of 14.34%wb, the rotor speed should be 600 to 700 rpm (13.2 to 15.4 m/s) and the feed rate of 720 kg/h so that the breakage and loss of grain would be low.

T. A. Adekanye et al (2016) tested a soybean thresher designed, constructed and evaluated at Landmark University, Omu-aran, Kwara State in Nigeria in order to determine how to mitigate impact and problems in soybean threshing of small farmers, to improve the TGX 1448 cultivar at the moisture contents of 10%, 16%, and 22%wb, rotor speeds of 320, 385, 450 and 515 rpm, by feeding 600 g of materials continuously. The concave clearance was 23 mm. They found that the threshing efficiency, cleaning efficiency, percentage of breakage and percentage of loss, and operational capacity were 99.51%, 77.91%, 3.72%, 31.33%, 4.43% and 35.44 kg/h, respectively. This experiment revealed that the threshing efficiency was between 98.96% to 99.88% within the range of rotor speeds of 320-515 rpm, and the cleaning efficiency reduced from 90.81% to 64.25% since the speed increased from 320 to 515 rpm at the moisture content of 10 to 22%wb.

It can be seen that most of the past research was performed on the threshing unit and the soybean combine harvester adapted from the axial flow rice threshing unit. Such adaptation still has problems to solve, such as the threshing system, separating and cleaning. Therefore, designing the threshing unit for a small soybean combine harvester to be installed with a farm tractor necessitates knowledge and understanding of design parameters and operational behaviors of an axial flow threshing unit. These would enable more accurate and appropriate design. Besides, the new body of knowledge was acquired in the use of a model to predict soybean threshing performance. Development of a combine harvester attached to a tractor required many sets of devices, and the threshing unit was very important to the performance both in terms of operation capacity and the quantity and quality of produces. This research emphasized the testing of operational factors of a short axial flow soybean threshing unit with a rotor length of 0.7 m. The past research results of soybean threshing units may not yield satisfactory results in the utilization. Hence, the operation of a short axial flow soybean threshing unit installed with a small tractor should be studied in order to further develop the machine in the future.

2 Materials and Methods

2.1 *Equipment used in the test*

The major components of the axial flow soybean threshing unit in the test included 6 rows of circular rotor rods, the lower threshing mesh and concave mesh attached to the upper concave drum. The angles of the 3 guide vanes were adjustable. The speed of the feed conveyor could also be adjusted. The rotor had a diameter of 0.48 m and was 0.70 m long. The 3 HP (2.23 kW) 220 V electric motor was used. The soybean cultivar used in the test was Chiangmai 60, which is the popular cultivar grown in the northeastern region of Thailand. The test of axial flow soybean threshing unit performance was carried out at the workshop, with the peg tooth clearance (PC) of 41.4 mm, concave clearance (CC) of 20 mm, and guide vane inclination (GI) of 80 degrees.

Figure 1 Testing of soybean threshing unit at a workshop

2.2 *Experimental planning*

The experimental parameters comprised grain moisture content. The data was statistically analyzed by using completely randomized design (CRD), the moisture contents of three levels, i.e., 14.94, 23.55

and 36.04 %wb. The RS and the FR were controlled at 10 m/s and 150 kg/h respectively.

2.3 *Testing method*

The physical properties of soybean pods and grains and the proportion of grain per non-grain were determined. The samples were dried in an oven to calculate the grain moisture content and non-grain moisture content in order to determine the parameters and levels of parameters according to the experimental plan. Next, the threshing unit was switched on. The test proceeded until all of the materials were expelled from the threshing unit before the machine was switched off. The fallen grains through the mesh into the chute were weighed, sorted and cleaned. Grains attached to pods at the discharge were disposed and percentages of loss and breakage were calculated.

Figure 2 Preparation for testing the working parameters

2.4 *Indicating parameters*

The indicating parameters for the study of the small axial flow soybean threshing unit included threshing efficiency, unthreshed loss, separating loss, total loss and breakage from threshing, which could be calculated as follows:

Threshing Efficiency (TE) or the amount of soybean grain discharged through the outlet compared to the feeding amount in percentage by weight:

$$TE\ (\%) = 1 - \left[\frac{W_1+W_2}{T}\right] \times 100 \qquad (1)$$

When TE was the threshing efficiency (%), W_1 was the amount of soybean grain in pods at the outlet (gram), W_2 was the amount of soybean grain in pods discharged at the straw outlet (gram) and T was the total feed amount (gram).

Total loss (TL) means the loss from threshing and loss from separation in percentage by weight:

$$TL\ (\%) = UL + SL \qquad (2)$$

When TL was the total grain loss (%), UL was unthreshed loss (%), and SL was loss from separating (%)

Grain breakage (GB) means the amount of broken grain discharged through the grain outlet compared to the total feed amount in percentage by weight:

$$GB\ (\%) = \frac{D_2}{T} \times 100 \qquad (3)$$

When GB was the percentage of breakage (%), D2 was the amount of grain discharged through the grain outlet (gram), and T was the total feed amount (gram).

3 **Results and Discussion**

3.1 *Effects of grain moisture content on performance of soybean threshing*

The effects of grain moisture content on the performance of the short axial flow soybean threshing unit are shown in Table 1. The control parameters were designed with peg tooth clearance (PC) of 41.4 mm, concave clearance (CC) of 20 mm, guide vane inclination (GI) of 80°, rotor speeds (RS) of 10 m/s and feed rates (FR) of 150 kg/h.

Analysis of the performance variation of the axial flow threshing unit showed that significantly affected threshing efficiency (TE), total loss (TL) and grain breakage (GB) of soybean.

Table 1 Analysis of variance of loss from the thresher unit, threshing performance, loss and grain breakage affected by moisture content, rotor speed and feed rate

Source of variation	df	TE (%)	TL (%)	GB (%)
Moisture Content (MC)	2	138.24 **	12.38 **	9.14 *

** = Significant at p<0.01; * = Significant at p<0.05, ns = not significant
TE = Threshing Efficiency, TL = Total Loss, GB = Grain Breakage

Grain moisture content (MC) significantly affects threshing efficiency and total loss at the reliability level of 99% while grain breakage at the reliability level of 95%. The high moisture content results in great friction between grain and non-grain materials. In addition, the adherence force between grain and pods is also high, which leads to an impact on threshing and more difficulty in removal of non-grain materials in the threshing unit than for grain with low moisture content. Soybean with high moisture content usually makes threshing and grain separation in the axial flow thresher more difficult, and in turn, leads to unthreshed loss.

3.2 Effects of grain moisture content on threshing efficiency

The following graphs depict the correlation between grain moisture content (MC) on threshing efficiency (TE) is shown in figure 3.

High grain moisture content lowers threshing efficiency; the moisture content in soybean stem and pods make threshing more difficult. This agrees with the study of Chinsuwan et al. (1997), which found that high moisture content in rice makes threshing and cleaning more difficult.

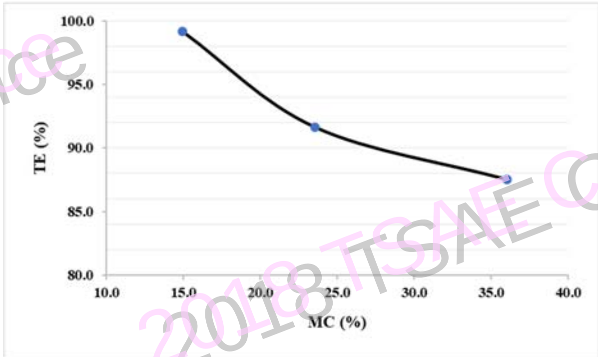

Figure 3 Effects of MC on threshing efficiency

3.3 Effects of grain moisture content on total loss

The correlation between soybean grain moisture content (MC) which affects total loss (TL) is shown in figure 4. The total loss increased when the moisture content of soybean grain increase; it is reduced when grain moisture content is low.

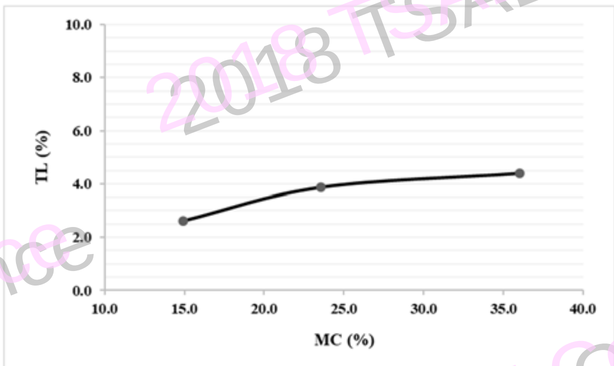

Figure 4 Effect of MC on total loss

When the soybean grain moisture content is high, the total loss becomes high, too. This is because the soybean stems and pods also contain high moisture, making it difficult for grain to become loosened from the pods and stems. In addition, the toughness of pods and stems make separation of grain more difficult. This is consistent with the study by Chuan-Udom et al. (2009), which showed that if rice grain and straw have high moisture content, the loss will occur from the threshing of rice cultivar known for difficult threshing.

3.4 Effects of grain moisture content on grain breakage

Figure 5 illustrates the correlation between grain moisture content (MC) which affects grain breakage percentage (GB).

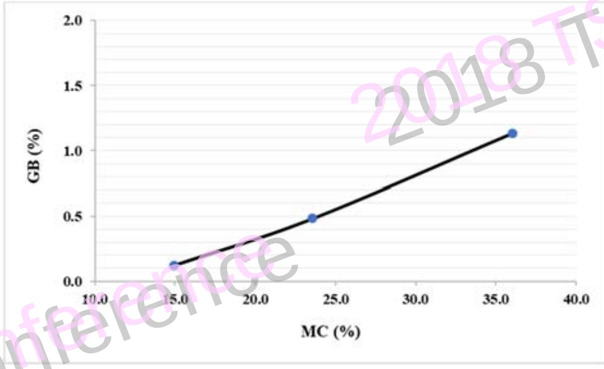

Figure 5 Effects of MC on grain breakage

When the soybean grain moisture content is higher than 15%wb; increase the percentage of grain breakage. This is consistent with the study conducted by Chinsuwan et al. (2003), which showed that the rice axial flow threshing unit operated with increased moisture content will increase the percentage of grain breakage. Gummert, et al. (1992) also stated that increased moisture content leads to higher grain breakage.

4 Conclusions

The experiment on the short axial flow soybean threshing unit designed to find the soybean threshing performance with different rotor speeds, feed rates, and grain moisture contents demonstrates the following:

1) Soybean grain moisture content has significant effects on threshing efficiency, total loss and percentage of grain breakage. Soybean with high moisture content results in decreased threshing efficiency. The percentage of breakage increases sharply when the grain moisture content is higher than 15%wb.

2) At the moisture content greater than 24%wb, increase threshing efficiency is higher, but slightly increases the total loss. However, when the soybean moisture content is higher than 15%wb, increased rotor speed will rapidly increase the percentage of grain breakage.

3) Soybean should be threshed at the grain moisture content not exceeding 15%wb.

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6 References

Adekanye, T. A., Osakpamwan, A.B. and Osaivbie, I.E. (2016). "Evaluation of soybean threshing machine for small scale farmer." Agricultural Engineering International: CIGR Journal. [Online]. Available: http://www.cigrjournal.org, 18(2): 426-434 [Accessed: May 2016].

Chinsuwan; W., Krisanaseranee; S., Mongkolthanatas, J. and Thongsawatwong, P. (1990). "Final report: Soybean Postharvest Technology Project (Technical Evaluation)." A report Submitted to the International Development Research Centre (IDRC). November 1990. 87p.

Chamsing, A. 1996. "A Study on the Use of Rice Combine Harvester for Harvesting Soybean," Master of Engineering Thesis in Agricultural Machinery, Graduate School, Khon Kaen University.

Chinsuwan, W., Mongpraneet, S. and Panya, N. 1997. "Optimum Harvest Period for Hommali Rice using Combine Harvester." KKU Research Journal; 2(1): 54-63.

Chinsuwan, W., Pongjan, N., Chuan-udom, S. and Phayom, W. 2003. "Effects of Threshing Bar Inclination and Clearance Between Concave Rod on Performance of Axial Flow Rice Thresher." KKU Research Journal. 8(1), 55-62.

Chirattiyangkur, A., Nakqoue, T., Kiatiwat T. and Usaborisut, P. 2006. "Design and development of a tractor mounted soybean combine harvester." Kasetsart Engineering Journal. 58(19), 40-48.

Chuan-udom, S. and Chinsuwan, W. 2009. "Threshing unit losses prediction for Thai axial flow rice combine harvester," Agricultural Mechanization in Asia, Africa and Latin America., 40(1): 50–54.

Gummert, M., Kutzbach, H.D., Muhlbauer, W., Wacker, P. and Quick, G.R. (1992) "Performance Evaluation of an IRRI Axial-flow Paddy Thresher." Agricultural Mechanization in Asia, Africa and Latin America, 23(3) 47-58.

Rojanasaroj, C., Chakkapak, J., Vejasit, A. Krisanaseranee, S. and Thongsawatwong. P. (1989) "Rice/Soybean Thresher." Present paper at Pai-rin Hotel, Phitsanulok. July 27-28, 1989. 24 p.

Sirisomboon, P. 1992. "Research and development thresher of small rice and soybean on the study of hold-on and throw-in." Department of Agricultural Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Office of Technology Promotion and Transfer. [Online]. Available: http://www.clinictech.most.go.th [Accessed: February 2016].

Thanisorn Nakqoue. (1994). "Design and development of a tractor-mounted soybean combine harvester," Master of Engineering Thesis in Agricultural Engineering, Kasetsart University; 184 p.

Thongsri K., Wannasai N., Punnara N. and Buakete S. (2015). "Studies on Harvesting Date and Harvesting Methods on Yield and Seed Quality of Soybean." The 53rd Kasetsart University Annual Conference. 3-6 February 2015, 218-225p.

Vejasit, A. 1991. "A Comparison between Peg Tooth and Rasp Bar Cylinders for Soybean Threshing Using Axial Flow Thresher," Master of Engineering Thesis in Agricultural Machinery, Graduate School, Khon Kaen University.

Vejasit, A. and Salokhe, V.M. "Studies on Machine-Crop Parameters of an Axial Flow Thresher for Threshing Soybean." Agriculture Engineering International: the GIGR Journal of Scientific Research and Development. Manuscript PM 04 004. July, 2004.