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Factors of Operation Affecting Performance of a Short Axial-flow Soybean Threshing Unit

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Abstract. This study aimed at investigating the operational factors that affect the performance of a short axial-flow soybean unit. 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, and guide vane inclination (GI) of 80°. The investigated factors included grain moisture content (MC), rotor speed (RS), and feed rate (FR). The split-plot experiment was planned by setting the main plots of soybean moisture contents at three levels, i.e., 14.94, 23.55 and 36.04%wb and the sub-plot of 3 x 3 factorial RCBD treatment: the rotor speed as the first factor having 3 levels, i.e., 7.54, 10.01 and 12.56 m/s; and the feed rate as the second factor with 3 levels, i.e., 100, 150 and 200 kg/h. The experiment demonstrated that the MC and the RS significantly affected the threshing efficiency, unthreshed loss, separating loss, total loss, and percentage of breakage. The FR was found to significantly affect threshing efficiency and percentage of breakage but not on unthreshed loss, separating loss and total loss. The short axial-flow soybean threshing unit is recommended for soybean moisture content of not over 16%wb and rotor speeds between 10 to 12 m/s, while feed rates should not exceed 150 kg/h.

Keywords: Soybean threshing, axial-flow thresher, soybean combine harvester.

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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 0.02ha/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 [1]. 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 [2]. 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 [3-4]. 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 [3]. 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 [5]. 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 [6]. 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 [7] 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. A. Chirattiyangkur et al. [8] design and development of a tractor mounted soybean combine harvester 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

H. Shouyin and C. Haitao [9] performed a study on the performance of a vertically axial flow soybean combine harvester in order to find the effect on threshing, separating, and cleaning based on 4 parameters, i.e., linear speed of rotor, concave clearance (CC), feed rate, and grain moisture content. Their experiment showed the most appropriate moisture content of 14-20%wb, rotor's linear speed of 6.5-8.3 m/s, CC of 15 mm, and feed rate of 144 kg/h; which yielded 1.0% of grain breakage, 0.5% of contaminants, 2.0% of unthreshed grain, 0.7% of grain in pods, with no grain fall and left-over.

L. Ruoxi and C. Haitao [10] studied the operation parameters affecting the efficiency of a prototype and showed that the appropriate operation factors were: grain moisture content of 17.5%wb, linear speed of 1.52 m/s, feed rate of 126-144 kg/h, concave clearance of 12-18 mm. These resulted in 0.03% contamination, 0.15% grain breakage, 1.15% separation loss, 0.35% unthreshed loss, 0.25% cleaning loss. All of the parameters agreed with the efficiency index of the Chinese soybean thresher Model NY/T1014-2006.

A. Vejasit and V.M. Salokhe.[11] 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 kW at 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.

A. K. Zaalouk [12] investigated the possibility of a rice thresher made in Thailand for dry peas and chose the appropriate operation condition. The finding indicated that the thresher could be used for peas under the condition of 9.20%wb of grain moisture content, threshing speed of 15.38 m/s, and feed rate of 20 kg/min. These rates yielded 2.17% damage, with 1.48% unthreshed grain, 98.52% threshing efficiency; using 14.70 kw of power and the operation cost of 143.20 L.E/ton.

T. A. Adekanye et al. [13] 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. Material 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.

Fig. 1. Guide vanes attached to the upper concave drum.

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Fig. 2. The feed conveyor with adjustable feed rate.

Fig. 3. Testing of soybean threshing unit at a workshop.

2.2. Experimental Planning

The experimental parameters comprised grain moisture content, rotor speed, and feed rate. The experimental design was a split plot with the main plot being the moisture contents of three levels, i.e., 14.94, 23.55 and 36.04%wb which covers the moisture contents range of harvested soybeans in general. In the sub-plot, the treatment was designed as a 3x3 factorial in RCBD, with the first factor being 3 rotor speeds (RS): at 7.54, 10.01 and 12.56 m/s and the second factor being 3 feed rates: 100, 150 and 200 kg/h.

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.

Fig. 4. 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:

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

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).

Unthreshed grain loss (UL) means the amount of grain in pods discharged at the straw outlet compared to the total feed amount in percentage by weight:

$$UL\ (\%) = \frac{W_2}{T}\ x\ 100 \tag{2}$$

When UL was the unthreshed loss (%), W_2 was the amount of grain in pods discharged at the straw outlet (gram), and T was the total feed amount (gram).

Separating loss (SL) means the amount of fallen grain and broken grain discharged through the straw outlet compared to the total feed amount in percentage by weight:

$$SL\ (\%) = \frac{W_3 + D_1}{T}\ x\ 100 \tag{3}$$

When SL was the separating loss (%), W_3 was the amount of fallen grain and broken grain discharged through the straw outlet (gram), D_1 was the amount of broken grain discharged through 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:

$$TL\ (\%) = UL + SL \tag{4}$$

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:

$$GB\ (\%) = \frac{D_2}{T}\ x\ 100 \tag{5}$$

When GB was the percentage of breakage (%), D_2 was the amount of grain discharged through the grain outlet (gram), and T was the total feed amount (gram).

2.5. Model on Performance of Soybean Threshing

The quadratic equations were developed to analyze the effects of the parameters on the threshing efficiency and losses based on the design was a split plot with the main plot being the moisture contents of three levels. In the sub-plot, the treatment was designed as a 3x3 factorial in RCBD. The equations were developed to model on the performance by elimination method. The effects of each parameter on the coefficients of determination (R^2), standard error (SE), and P-value.

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3. Results and Discussion

3.1. Effects of Moisture Content, Rotor Speeds and Feed Rates on Performance of Soybean Threshing

The effects of moisture content, rotor speeds and feed rates on the performance of the short axial flow soybean threshing unit are shown in Table 1. The tested parameters were set at the rotor speeds (RS) of 7.54-12.56 m/s and the feed rates (FR) of 100-200 kg/h. The control parameters were designed with peg tooth clearance (PC) of 41.4 mm, concave clearance (CC) of 20 mm and guide vane inclination (GI) of 80°.

Analysis of the performance variation of the axial flow threshing unit showed that rotor speeds (RS) significantly affected threshing efficiency (TE), unthreshed loss (UL), separating loss (SL), total loss (TL), and grain breakage (GB) of soybean at the reliability level of 99%. When the rotor speed was high, threshing became rapid and violent resulting in soybean grain damage and loss. However, increased rotor speeds reduced loss from the threshing system owing to the centrifugal force that released the grain from the pods through the mesh. It can be concluded that varied rotor speeds have an effect on grain loss.

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(%)	UL(%)	SL(%)	TL(%)	GB(%)
Block	2	< 1 ns	< 1 ns	2.44 ns	2.56 ns	< 1 ns
Rotor Speed(RS)	2	144.05 **	31.77 **	28.55 **	8.50 **	49.18 **
Feed Rate (FR)	2	8.54 **	1.30 ns	< 1 ns	< 1 ns	7.06 **
Moisture Content (MC)	2	350.24 **	136.40 **	22.46 **	72.79 **	89.84 **
RS*FR	4	1.17 ns	1.99 ns	< 1 ns	< 1 ns	2.46 ns
RS*MC	4	20.23 **	17.49 **	8.39 **	10.94 **	15.09 **
FR*MC	4	3.82 **	< 1 ns	< 1 ns	< 1 ns	6.15 **
RS*FR*MC	8	2.48 *	1.56 ns	2.20 *	1.80 ns	1.55 ns

** = Significant at $p<0.01$; * = Significant at $p<0.01$, ns = not significant
TE = Threshing Efficiency, UL = Unthreshed Loss, SL = Separated Loss, TL = Total Loss,
GB = Grain Breakage

Feed rates (FR) significantly affect threshing efficiency and grain breakage at the reliability level of 99%. However, they do not have any significant effect on unthreshed loss, separating loss and total loss. This is because increased materials fed into the threshing unit result in tardiness of threshing and grain separating. In addition, the friction between materials and the thresher increases, leading to threshing violence and grain damage.

Moisture content (MC) significantly affects threshing efficiency, unthreshed loss, separating loss, total loss, and grain breakage at the reliability level of 99%. 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.

The correlation between rotor speed and feed rate has no significant effect on threshing efficiency, unthreshed loss, separating loss, total loss, and percentage of grain breakage.

The correlation between rotor speed and grain moisture content has a significant effect on threshing efficiency, unthreshed loss, separating loss, total loss, and percentage of grain breakage at the reliability level of 99% owing to the high rotor speed that affects threshing system.

The correlation between feed rate and grain moisture content has a significant effect on threshing efficiency and percentage of grain breakage at the reliability level of 99%, but has no significant effect on unthreshed loss, separating loss and total loss.

The correlation between rotor speed and feed rate and grain moisture content has a significant effect on threshing efficiency and separating loss at the reliability level of 99%, but has no significant effect on unthreshed loss, total loss and percentage of grain breakage.

3.2. Model of Soybean Testing Performance

Model 1 in Table 2, indicating the relationship between grain moisture content (MC), the feed rate (FR) and the rotor speed (RS) affecting the threshing efficiency (TE) from the threshing unit shown in Fig. 5. Model 2 indicating the relationship between MC and RS affecting the unthreshed loss (UL) from the threshing unit shown in Fig. 6. Model 3 indicating the relationship between MC and RS affecting the separating loss (SL) from the threshing unit shown in Fig. 7. Model 4 indicating the relationship between MC and RS affecting the total loss (TL) from the threshing unit shown in Fig. 8 and model 5 indicating the relationship between MC, FR and RS affecting the grain breakage (GB) from the threshing unit shown in Fig. 9.

Table 2. Regression analysis of moisture content (MC), rotor speed (RS) and feed rate (FR), with effects on loss from the threshing performance.

Model	Equation	R^2	SE	*p*-value
1	$TE = 93.05 - 2.1\ MC - 0.033\ FR + 5.044\ RS - 0.3\ RS^2 + 0.002\ MC{*}FR + 0.112\ MC{*}RS$	0.969	1.50384	<0.001
2	$UL = 0.313 + 0.129\ MC - 0.328\ RS + 0.024\ RS^2 - 0.01\ MC{*}RS$	0.908	0.12664	<0.001
3	$SL = -1.777 + 0.148\ MC + 0.442\ RS - 0.011\ MC{*}RS$	0.771	0.29150	<0.001
4	$TL = -3.8 + 0.277\ MC + 0.602\ RS - 0.021\ MC{*}RS$	0.880	0.864	<0.001
5	$GB = 7.986 - 0.308\ MC + 0.015\ FR - 1.644\ RS + 0.003\ MC^2 + 0.066\ RS^2 + 0.035\ MC{*}RS$	0.936	0.34475	<0.001

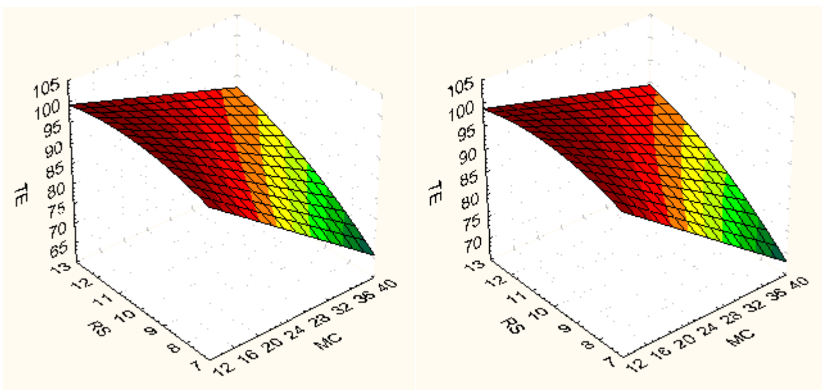
3.3. Effects of Operating Factors on Threshing Efficiency

The following graphs depict the correlation between grain moisture content (MC) and rotor speed (RS) on threshing efficiency (TE) at the feed rates (FR) of 100, 150, and 200 kg/h (Fig. 5).

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. [14], which found that high moisture content in rice makes threshing and cleaning more difficult.

Higher rotor speeds increase greater threshing efficiency since threshing violence results in better scouring. This is consistent with the study by Vejasit et al. [11-15] and Pholpo et al. [16], which found that threshing soybean with an axial flow thresher with higher rotor speeds, i.e., at 10.7-14.7 m/s, yields higher threshing efficiency.

Increased feed rates lower threshing efficiency because of the increase of materials in the threshing chamber, leading to breakage of grain and blockage of material beaten on the mesh. This finding is not consistent with the study by Vejasit et al. [11-15], who showed that feed rate has no effect on soybean threshing efficiency.



(a) (b)

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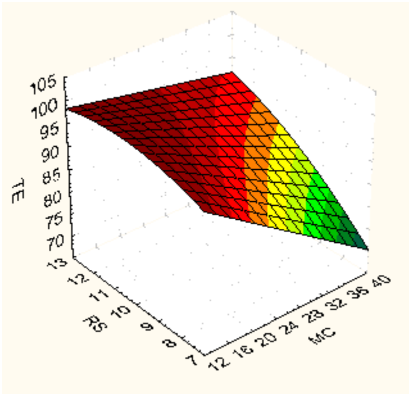

(c)

Fig. 5. Effects of rotor speed and moisture content, at FR (a) 100 kg/h, (b) 150 kg/h, and (c) 200 kg/h on threshing efficiency.

3.4. Effects of Operating Factors on Unthreshed Grain Loss

The correlation between grain moisture content (MC) and rotor speeds (RS) which affect the percentage of unthreshed loss (UL) is shown in Fig. 6. The feed rate (FR) has no correlation with rotor speed (RS) and moisture content (MC) at the moisture content lower than 24%wb. The low rotor speed may lead to the loss. With the moisture content higher than 24%wb, the unthreshed loss becomes higher when the rotor speed is lower because the increase of rotor speed raises threshing strength and hence reduced unthreshed loss. This finding agrees with Gummert, et al. [17] and Saeng-Ong, et al. [18], who stated that increase of violence in rice threshing means reduced unthreshed loss provided that the moisture content is between 20.6-32.1%wb.

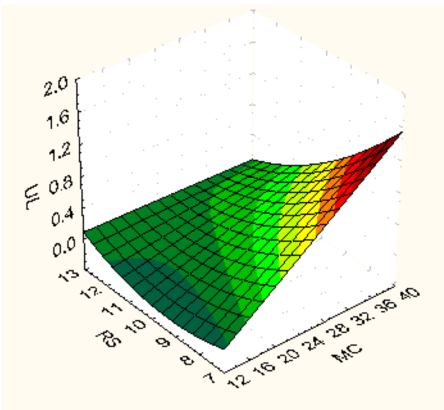

Fig. 6. Effects of rotor speed and moisture content on unthreshed loss.

3.5. Effects of Operating Factors on Separating Loss

The correlation between soybean grain moisture content (MC) and rotor speed (RS) affecting the percentage of separating loss (SL) is illustrated in Fig. 7. The feed rate (FR) does not correlate with rotor speed (RS) and moisture content (MC).

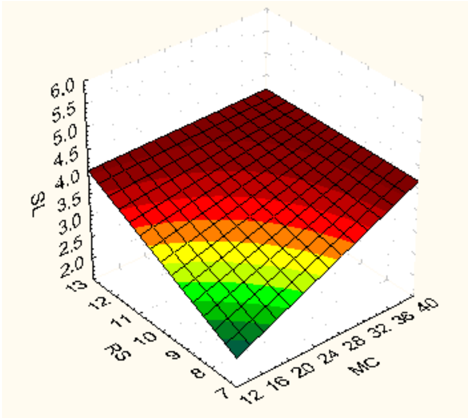

Fig. 7. Effects of rotor speed and moisture content on separating loss.

With the increased grain moisture content, separating loss increases owing to the fact that the pods and stems also have high moisture content. This means difficulty to thresh grains from pods and stems. Moreover, the toughness of stems and pods make removal of grain more difficult. Chuan-udom et al. [19] and Srison, et al. [20], likewise, said that high moisture content of rice grain and straw affects unthreshed loss especially for the rice cultivar that is by nature difficult to thresh.

Increased rotor speed increases separating loss, especially when the grain moisture content is lower than 24%wb. This is because higher rotor speed means increased violence and the centrifugal force of threshing which could break the stem and pods with the moisture content lower than 24%wb. The broken materials could also block the mesh and hence more grain is discharged through the straw outlet. At the moisture content higher than 24%wb, rotor speeds do not affect separating loss. This contrasts with the finding of Gummert, et al. [17], who said that increase of centrifugal force in rice threshing at the moisture content of 20.6-32.1%wb enables more grain to pass through the mesh and hence reduced separating loss.

3.6. Effects of Operating Factors on Total Loss

The correlation between soybean grain moisture content (MC) and rotor speed (RS) which affects total loss (TL) is shown in Fig. 8. The total loss increased when the moisture content of soybean grain and rotor speed increase; it is reduced when grain moisture content and rotor speed are low. The feed rate (FR) does not have any correlation with RS and MC.

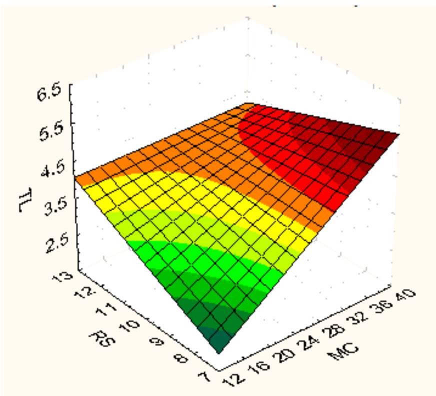

Fig. 8. Effect of rotor speed and moisture content on total loss.

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. [19], 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.

Increased rotor speed results in a greater total loss, especially when the grain moisture content is lower than 24%wb. This is because of the increased violence and centrifugal force of threshing that result, which might cause soybean stems and pods with the moisture content lower than 24%wb to break and block the mesh. Increasing amount of grain cannot pass through the mesh and is sent to the straw discharge. At a moisture content greater than 24%wb, the rotor speed may slightly increase total loss as well as separating loss.

3.7. Effects of Operating Factors on Grain Breakage

Figure 9 illustrates the correlation between grain moisture content (MC) and rotor speed (RS), which affects grain breakage percentage (GB) at the feed rates of 100, 150, and 200 kg/h.

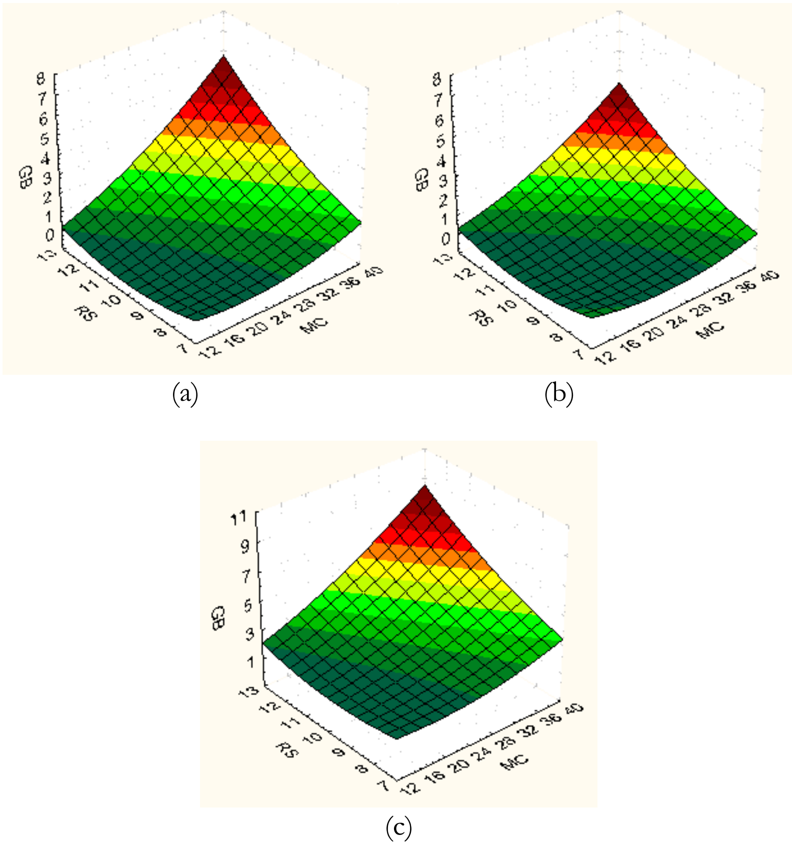

Fig. 9. Effects of rotor speed and moisture content at FR (a) 100 kg/h, (b) 150 kg/h, and (c) 200 kg/h on grain breakage.

At the grain moisture content of 16%wb, alteration of rotor speeds does not affect the percentage of breakage; however, when the grain moisture content is higher than 16%wb, increased rotor speed rapidly increases the percentage of grain breakage. This is consistent with the study conducted by Chinsuwan et al. [21-22], which showed that the rice axial flow threshing unit operated with increased rotor speed will increase the percentage of grain breakage. Gummert, et al. [17] also stated that increased rotor speed leads to higher grain breakage.

Higher feed rates slightly increase the percentage of grain breakage. Feeding greater quantity of materials means a higher proportion of soybean stems while the rotor speed remains the same. More grains are beaten or scoured in the threshing unit. Vejasit et al. [15], also showed that for the axial flow threshing unit used with soybean, the feed rates affect grain breakage when the rotor speed is 10.7-14.7 m/s; with grain breakage not very high but will increase when the rotor speeds increase to 16.7-18.7 m/s.

4. Conclusion

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, unthreshed loss, separating loss, total loss, and percentage of grain breakage. Soybean with high moisture content results in decreased threshing efficiency. The moisture content lower than 24%wb leads to low unthreshed loss. On the contrary, soybean moisture content greater than 24%wb increases unthreshed loss and also affects separating loss and total loss. The percentage of breakage increases sharply when the rotor speed is increased and the grain moisture content is higher than 16%wb.

2) Rotor speed has a significant effect on threshing efficiency, unthreshed loss, separating loss, total loss, and percentage of breakage. When the grain moisture content is lower than 24%wb and the rotor speed is increased, the threshing efficiency is higher and the unthreshed loss is lowered, while separating loss and total loss are higher. At the moisture content greater than 24%wb, increased rotor speeds increase threshing efficiency, and unthreshed loss is higher when the rotor speed is decreased. Rotor speed does not affect separating loss but slightly increases the total loss. The change of rotor speed does not make the percentage of breakage become higher when the moisture content is lower than 16%wb. However, when the soybean moisture content is higher than 16%wb, increased rotor speed will rapidly increase the percentage of grain breakage.

3) The feed rate significantly affects threshing efficiency and percentage of breakage but does not affect unthreshed loss, separating loss, and total loss.

4) Soybean should be threshed at the grain moisture content not exceeding 16%wb. The rotor speeds should be use 10 to 12 m/s, while the feed rate should not exceed 150 kg/h.

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