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Analysis of the Separating Performance of Peanut Harvester Sorting System

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This study examined the performance of the separating system of a self–propelled peanut harvester by analyzing the relationship between a shaking screen and rotational speeds of winnowing. The shaking screen was manufactured to have rotational speeds of 370, 470, 570 rpm and winnowing was manufactured to have rotational speeds of 1,500, 1,760, 2,020 rpm by adjusting the pitch circle diameter of each pulley. The sample was prepared based on the yields of an actual self–propelled peanut harvester and analyzed with Statistical Analysis Software after measuring the weight of peanuts and stems. The stem separation ratio was high as 95.3% when rotational speeds were 570 rpm (shaking screen) and 2,020 rpm (winnowing). The peanut loss ratio was low as 0% when rotational speeds were 370 rpm (shaking screen) and 1,500 rpm (winnowing). The results indicated that the stem separation ratio was improved with high rotational speeds of shaking screen and winnowing; the peanut loss ratio was reduced with low rotational speeds of shaking screen and winnowing. However, the rotational speed of winnowing did not influence on the peanut loss ratio; as a result, separation performance was improved with low rotational speed of shaking screen and high rotational speed of winnowing. Low rotational speed of shaking screen, however, may cause congestion during process, thus follow–up studies are needed.

Key words: Peanut Harvester, Separation Method, Winnowing part, Shaking screen, Rotational speed

INTRODUCTION

Peanuts are healthy high calorie food containing unsaturated fatty acids and protein, and they have been processed into various types of food such as cooking oil (Kim, 2008). Roasted peanuts for snack foods are consumed mostly in Korea.

Peanut growing area in Korea has been reduced from 4,662 ha (in 2000) to 3,352 ha (in 2005) due to the opening market for agricultural products in 1990s (MIFAFF, 2006). However, since 2008, growing area and peanut production have increased up to 5,381 ha and 11,400 ton in 2010 as peanut consumption for eating between meals increased (MIFAFF, 2010). Farmers prefer growing green peanuts because the products were harvested early and had competitiveness over the imported dried peanuts. Growing green peanuts have several advantages compared with growing dried peanuts in terms of products and post–processing labor. They reduce quantity decrease due to defects and diseases, and they can be shipped without post–processing such as drying and storage. However, green peanuts are grown and harvested with vinyl covering; consequently, the vinyl need to be removed by hand after the harvesting (Kim, 2008).

Agricultural mechanization for field crop is still in the developing stage (47.2%) in Korea. Over 90% of mechanization is for plowing, cultivating, and control, but mechanization for sowing, transplantation and harvesting is low as 10% (MIFAFF, 2007). Peanuts produce their fruit underground; therefore, harvesting process is complicated, and labor up to 34% of the entire process is required for harvesting (MIFAFF, 2010). Furthermore, peanuts have harvesting time of 20 days, which is the same period with rice harvesting time and therefore it is hard to seek labor workers in this season. To solve these problems, a self–propelled peanut harvester (rated power of 44.13 kW) was developed by T Company, and it was composed of digging part, threshing part, separating part, and collecting part. The separating part should be optimized first because work efficiency of a self–propelled peanut harvester was influenced by the performance of the separating part. In order to provide optimum conditions for designing the separating system, experiments are needed to identify the factors that contribute to high stem separation ratio and low peanut loss ratio with shaking screen and winnowing. However, low rotational speed of shaking screen may not facilitate the separating capacity.

The objective of this study was to analyze the peanut loss and separating performance through the experiments with shaking screen and winnowing. The results of this study will contribute to improving performance of separating system of the peanut harvester by selecting optimum rotational speeds of shaking screen and winnowing.

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MATERIALS AND METHODS

Self–propelled peanut harvester

A self–propelled peanut harvester that has rated engine speed of 2,600 rpm and rated power of 44.13 kW was used for this study. The harvester was composed of digging part, threshing part, separating part, and collecting part as shown in Figure 1. The experiments were conducted in a stationary state, and the specifications of the harvester are shown in Table 1.

Separating system

Figures 2 and 3 show the separating system including shaking screen and winnowing. The separating system of the peanut harvester includes a shaking screen and winnowing. Mixtures of peanut pods with other foreign materials that passed through digging part, threshing part, and separating part were conveyed to the shaking screen where dirt fell through. A plate was attached under the shaking screen to guide airflow from the winnowing, and it separated pods from small vine material and other foreign material (vinyl) which were transferred rearward by the shaking screen. Mesh size of the shaking screen was 14×120 mm^2. The width of the whole screen was 610 mm, and the length was 1,315 mm. The shaking screen generated a swing by reciprocating motion of the eccentric cam shaft with 4–bar linkage, and blades were attached to the rear of the shaking screen to prevent the inflow of stems. The winnowing had six blades, and air was controlled by adjusting opening area of air inlet.

In order to evaluate the performance of the separating system, the weight of the separated peanuts was measured. Stems were collected at the air outlet and peanuts were collected from the conveying part. Therefore, a collecting box (Collecting box 1) for the stems was installed on the outlet side as shown in the Figure 4, and the peanuts delivered from the conveying part were collected in a bag (Collecting box 2) after each experiment.

The peanuts were separated from vines and other materials by the rotational speed of shaking screen and wind velocity from winnowing. Pulleys were manufac-

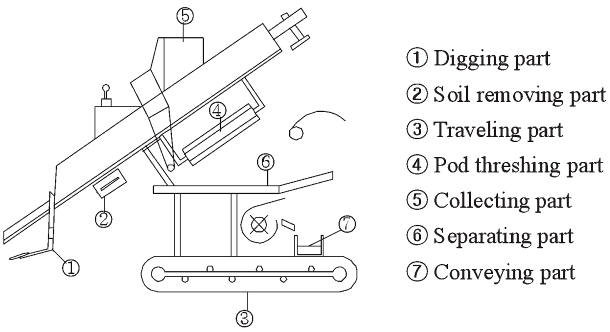

Fig. 1. Configuration of self–propelled peanut harvester used in this study.

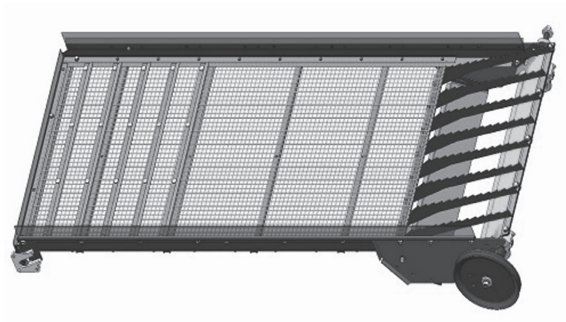

Fig. 3. 3D shape of shaking screen.

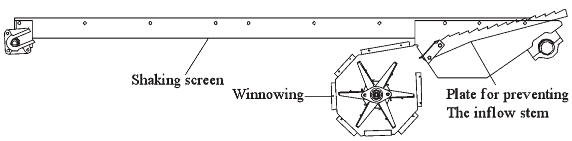

Fig. 2. Configuration diagram of the separating system.

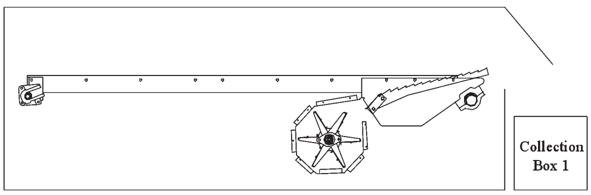

Fig. 4. Position of collection box(Collecting box 1).

Table 1. Specifications of the peanut harvester used in this study

Drive system	Dimensions	Overall height	4,600 mm
		Overall width	1,835 mm
		Weight	19,600 N
	Standard working speed		0~0.77 m/s
	Power		44.13 kW
Digging system	Digging method / Depth		Fixed type / 200 mm
	Number of Planting rows / Width		2 / 600 mm
Threshing system	Threshing method		Hitting type
Separating system	Separating method		Pitching + Winnowing
Collecting system	Collection method		Burlap bag type

tured to analyze the separating performance depending on the rotational speeds of shaking screen and winnowing. When the pitch circle diameter of a pulley for shaking screen was 205 mm, the rotational speed of the pulley was 470 rpm. When the pitch circle diameter of a pulley for winnowing was 120 mm, the rotational speed of the pulley was 1,500 rpm. Figure 5 shows the power transfer diagram of the separating system. Three different levels of rotational speeds (370, 470, and 570 rpm) of the pulley for shaking screen and three levels of rotational speeds (1,500, 1,760, and 2,020 rpm) of the pulley for winnowing were determined. Tables 2 and 3 show the sizes of pulleys for shaking screen and winnowing.

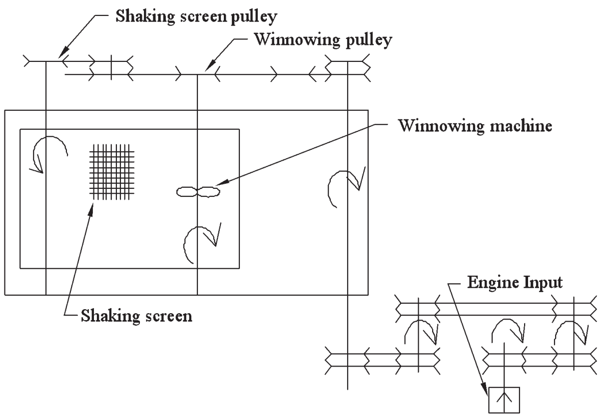

Fig. 5. Power transfer diagram of the separating system.

Table 2. Rotational speed on pulley size of shaking screen

Rotational speed (rpm)	Pulley size (PCD , mm)
370	260
470	205
570	170

Table 3. Rotational speed on pulley size of winnowing

Rotational speed (rpm)	Pulley size (PCD , mm)
1,500	120
1,760	110
2,020	105

Measuring devices

Factors of this experiment were the rotational speeds of the winnowing and shaking screen; therefore, the speeds should be checked first. The rotational speeds were measured using a laser speed meter. The experiments were conducted with three different levels of rotational speed. Factors of the experiments for separating stems were air intensity and airflow; therefore, intensity and flow of air should be measured depending on the rotational speed of winnowing. Air intensity was measured in indoor environment in order to eliminate the influence of the external environment. According to the CFD analysis of winnowing, air from the winnowing flowed mainly over the blades which were installed for preventing stem inflow, and it did not reach to the guide plate (Lee *et al.*, 2013). Thus, airflow speeds from the points 1, 2, 3, and 4 were measured as in Figure 6. A pinwheel type probe was used to measure airflow speed. The weights of collected peanuts and stems were measured using a scale.

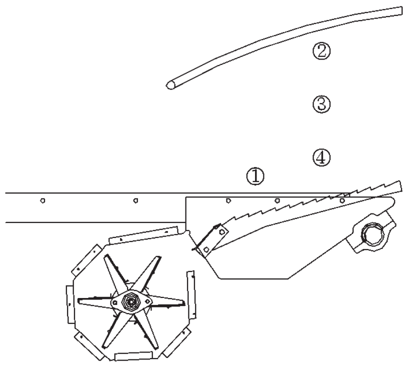

Fig. 6. Air flow speed measurement positions.

Sample

The same amount of peanuts as the one delivered to the separating system of an actual peanut harvester was prepared, because the experiment was conducted in a stationary state. The amount of sample was prepared based on harvesting performance test of an actual self–propelled peanut harvester at peanut field, Iksan, Jeonbuk Province. Table 4 shows the weights of peanuts and other foreign materials which were delivered to the shaking screen at three levels of working speeds (0.17, 0.30, and 0.41 m/s) in the working area of 9×1 m^2. Among the test results, the amount of peanuts was determined at the working speed of 0.3 m/s which showed the biggest harvest weight. When the person deliver the sample (peanut and other foreign material) to shaking screen directly, amount of the sample has to be similarly deliver at the working speed. Setting up the sample amount of factorial experiment in the working area of 2×1 m^2 (Table 5.)

Table 4. Performance test result of working speed

Working speed (m/s)	Peanut (g)	Stem (g)	Vinyl (g)
0.17	8,522	418	28
0.30	8,804	494	64
0.41	7,742	594	42

Table 5. Sample amount of factorial experiment

Sample	Weight (g)
Peanut	2,000
Vinyl	10
Stem	100

is based on the test result, which is the amount of peanuts was determined at the working speed of 0.3 m/s which showed the biggest harvest weight in 9×1 m^2. Table 5 shows the amount of sample (peanut, stem, vinyl) in the working area of 2×1 m^2. Sample was spread evenly on corrugated cardboard as in Figure 7. Variety name of the peanuts was PALPAL from a peanut field at Iksan, Jeonbuk Province.

Fig. 7. Sample shape of factorial experiment.

Method

Sample was delivered evenly to the shaking screen for six seconds, and three experiments were repeated with three different levels of rotational speeds: 370, 470, 570 rpm for shaking screen and 1,500, 1,760, 2,020 rpm for winnowing. Separating performance was analyzed with the collected peanuts, stems, and vinyl.

Analysis of the experiment

In order to identify the separating performance based on the shaking screen and rotational speeds of the pulley, the collected peanuts, stems, and vinyl were measured. The weight of vinyl was excluded because it was small. Peanut loss ratio was calculated using equation (1), and stem separation ratio was calculated using equation (2).

$$\text{Peanut loss ratio} = \frac{P_{m1}}{P_{m1} + P_{m2}} \times 100 \quad (1)$$

where, Peanut loss ratio (%)

Pm_1 = Peanut weight of collection box 1 (kg)
Pm_2 = Peanut weight of collection box 2 (kg)

$$\text{Stem separation ratio} = \frac{S_{m1}}{S_{m1} + S_{m2}} \times 100 \quad (2)$$

where, Stem separation ratio (%)

Sm_1 = Stem weight of collection box 1 (kg)
Sm_2 = Stem weight of collection box 2 (kg)

A two–way ANOVA in the statistical analysis is divided into the one with replication and without replication. It has some advantages in the repeated experiments with two factors. First, it determines the effect of combination of each factor. Second, it identifies if there is a significant interaction effect between them; as a result, it determines main effect and experimental error. Third, reproducibility and management state of the experiment can be reviewed from the repeated data. Forth, it detects the effect with small number of levels for the factors by increasing the number of repetitions. For these reasons, a two–way ANOVA was used to analyze the separating performance with two factors, shaking screen and rotational speeds of winnowing. MINITAB was used for distribution analysis.

RESULTS AND DISCUSSION

Results of separating performance test

Tables 6 and 7 show the analysis of peanut loss ratio and stem separation ratio from the separating performance test based on shaking screen and rotational speeds of winnowing. The ANOVA was used to determine the effect on peanut loss ratio and stem separation ratio based on the shaking screen and rotational speeds of winnowing, and Tables 8 and 9 show the dispersion analysis.

P–values of both rotational speeds of shaking screen and winnowing were less than significance level 0.005 at 95% of confidence interval; therefore, there were differences of stem separation ratio both in the rotational speeds of the shaking screen and winnowing. In addition, interaction effect between shaking screen and rotational speed of winnowing was not present. Stem separation ratio was 95.3% with the conditions that 570 rpm rotational speed for shaking screen and 2,020 rpm speed for winnowing.

P–value of rotational speeds of shaking screen was less than significance level 0.005 at 95% of confidence interval; therefore, there was difference of peanut loss ratio in the rotational speeds of the shaking screen. However, P–value of rotational speeds of winnowing was not less than significance level 0.005 at 95% of confidence interval; as a result, there was no difference of peanut

Table 6. Stem separator ratio at the rotation speed of the winnowing and of shaking screen

Winnowing \ Shaking screen	370 (rpm)	470 (rpm)	570 (rpm)
1500 (rpm)	77.3 %	82.0 %	82.6 %
1760 (rpm)	82.6 %	84.0 %	86.0 %
2020 (rpm)	92.6 %	92.0 %	95.3 %

Table 7. Peanut loss ratio at the rotation speed of the winnowing and shaking screen

Winnowing \ Shaking screen	370 (rpm)	470 (rpm)	570 (rpm)
1500 (rpm)	0.0 %	0.6 %	5.1 %
1760 (rpm)	0.2 %	1.6 %	4.1 %
2020 (rpm)	0.3 %	1.1 %	4.0 %

Table 8. Stem separator ratio of two–way factorial design (Minitab)

Source	DF[a)]	SS[b)]	MS[c)]	F[d)]	P[e)]
Rotational speed of shaking screen	2	57.556	28.778	9.84	0.001
Rotational speed of winnowing	2	764.667	382.333	130.67	0.000
Interaction	4	27.778	6.944	2.37	0.091
Error	18	52.667	2.926		
Total	26	902.667			

Notes, a) Degree of freedom, b) Sum of square, c) Mean square, d) F–value, e) P–value

Table 9. Peanut loss ratio of two–way factorial design (Minitab)

Source	DF[a)]	SS[b)]	MS[c)]	F[d)]	P[e)]
Rotational speed of shaking screen	2	87.896	43.948	86.93	0.000
Rotational speed of winnowing	2	2.509	1.254	2.48	0.112
Interaction	4	1.442	0.361	0.71	0.594
Error	18	9.1	0.506		
Total	26	100.947			

Notes, a) Degree of freedom, b) Sum of square, c) Mean square, d) F–value, e) P–value

Table 10. Result of wind velocity

Winnowing rotational speed	Point 1 (m/s)	Point 2 (m/s)	Point 3 (m/s)	Point 4 (m/s)
1500 (rpm)	6.2	2.0	2.4	4.1
1760 (rpm)	7.5	1.2	3.2	4.8
2010 (rpm)	9.0	1.1	3.4	6.0

loss ratio in the rotational speeds of the winnowing. In addition, interaction effect between shaking screen and rotational speed of winnowing was not present. Peanut loss ratio was 0% with the conditions that 370 rpm rotational speed for shaking screen and 1,500 rpm speed for winnowing. Separating performance was good in the conditions that lots of airflow and low rotational speed of shaking screen. However, current system could not increase the airflow any more. Furthermore, low rotational speed may make it ineffective in separating peanut pods from the vine.

Result of measuring air flow speed

Table 10 shows the airflow speed of indoor environment in a stationary state. Airflow speed at the point 1 of Figure 6 was 6.2–9 m/s, and the one at point 4 was 4.1–6 m/s. Airflow speed at the guide plate side (point 2) was low as 1–2 m/s, and the one at point 3 was low as 2.4–3.4 m/s.

SUMMARY AND CONCLUSIONS

This study examined the separating system of the peanut harvester to improve its performance. The study analyzed the peanut loss and stem separation depending on the varied rotational speeds of shaking screen and winnowing. The results analyzed by a two–way ANOVA can be summarized as follows:

1. The process of separating peanut pods from the vine was influenced by the rotational speeds of shaking screen and winnowing. The stem separation ratio was improved with high rotational speeds of shaking screen and winnowing.
2. Peanut loss ratio was only affected by the rotational speeds of shaking screen; the lower rotational speed reduced the peanut loss ratio.
3. From the results of this study, separation performance was improved with low rotational speed of shaking screen and high rotational speed of winnowing. However, low rotational speed of shaking screen may cause congestion during process, thus follow–up studies are needed.

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