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Development of Threshing Machine for Shatter-Resistant Sesame

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Abstract

Purpose: A threshing machine for shatter-resistant sesame was designed and developed in this study. **Methods:** Two types of sesame (shatter-resistant and conventional) were tested using the developed sesame threshing system. Three types of serrated bars were designed and evaluated through performance tests, in terms of the ratio of unthreshed sesame. **Results:** In the case of conventional sesame, the ratio of unthreshed sesame did not show any difference with bar type or cylinder rotation speed. For shatter-resistant sesame, however, the ratio of unthreshed sesame decreased with increased cylinder rotating speed for all three types of bar. **Conclusions:** These results are useful for the construction and utilization of an efficient threshing harvester. The type-L bar showed the best result in the energy equation.

Keywords: Cylinder speed, Serrated bar, Sesame, Shatter-resistant, Thresher

Introduction

Sesame seed, domesticated well over 3000 years ago, is one of the oldest oilseed crops. Its size, form, and color vary among thousands of varieties. Typically, the seeds are about 3 to 4 mm long by 2 mm wide and 1 mm thick. The seeds are ovate, slightly flattened, and somewhat thinner at the eye of the seed than at the opposite end. The kernel weight of the seeds is between 20 and 40 mg. (Oplinger et al., 1990)

For thousands of years, sesame seeds have been a source of both food and oil. Sesame has one of the highest oil contents; some varieties have over 50% oil content compared with soybean's 20%. Korea is one of the large sesame importers of sesame oil, particularly oil of roasted seed, because it is a major ingredient in many Korean foods.

Sesame can be harvested 90 to 150 days after planting. In general, the unbranched varieties mature earlier. The crop must be harvested before it is damaged by the first frost. The shattering and nonshattering types require different harvesting techniques. Caution is recommended to minimize seed damage and loss during harvesting (Oplinger et al., 1990).

Sesame is a highly profitable crop, but in order to reduce the cost of production even further, the mechanization of harvesting is essential (Lee and Kim, 2007, 2009a, and 2009b). Mechanization of some aspects of sesame farming, such as forming a ridge, mulching, and seeding, have been developed, but weeding and harvesting operations are entirely dependent on manual labor (Yilmaz et al., 2008). In addition, sesame is harvested in the fall, which is the rainy season in Korea, so a considerable amount of sesame is likely to be lost during the harvesting process (Noh, 2014).

Sesame should be threshed using a low cylinder speed (450 to 500 rpm). Screens also need to be adjusted for the small seed size. Nonshattering types can be combined directly at low cylinder speeds (Oplinger et al., 1990).

For mechanization of sesame harvesting, the physical shattering quality of sesame has been changed: shatter-resistant sesame has been bred and introduced to the farmer.

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Many researchers have studied shatter-resistant sesame, which has a smaller pod opening width than regular sesame seed, and remains in the pod after mature. The recently developed shatter resistant sesame reduces shattering losses caused by the harvesting process.

In this study, a threshing system for shatter-resistant sesame was designed so that the producer can save labor and time. The system not only solves the problem of the farmer, but also increases the usable farming area by mechanization. Three types of thresher teeth (serrated bar) were designed and evaluated by experiments.

Materials and methods

Sesame

The shatter resistance sesame (KS11) and conventional sesame (Hwangbaek) used in this experiment were planted in July 2011 and harvested in November 2011 in Suwon, Korea.

Separation factors for shatter resistant sesame

There are three types of factors for shatter-resistant sesame separation machines: mechanical, systemic, and material. One of the mechanical factors in the sesame separation system is the shape of the serrated bar, and the systemic factor is the rotational cylinder speed. The relevant materials factor is the moisture content of the sesame. This study focused on the mechanical and systemic factors.

Modification of thresher separation system

A threshing machine (BHD-1300) developed by Buheung Machinery Company (Jinju-si, Korea) was used in this study. The machine has dimensions of 970 mm (length), 1110 mm (width), and 1090 mm (height), and a weight of 132 kg. In addition, the rotational speed is about 300–400 rpm, and the rated power is 2 HP.

The rotating cylinder was modified for this thresher.

Design of serrated bars (i.e., blade)

Three types of serrated bars were designed to develop the appropriate thresher. The remaining portion was based on a conventional thresher.

When the threshing cylinder rotates, its kinetic energy (E) is expressed as:

$$E=\frac{1}{2}I_G\omega^2=\frac{1}{2}mK_G^2\omega^2 \qquad (1)$$

Where, I_G : mass moment of inertia (kg/m^2)
K_G : radius of rotation of threshing blade (m)
m : mass of cylinder (kg)
Ω : angular velocity (rad/s)

In Equation (1), the angular velocity and mass of the threshing cylinder is the same across the entire threshing cylinder, so the threshing kinetic energy (E) is proportional to the radius of the rotation of the threshing bar (i.e., blade). However, when the cylinder rotates, the full impact force generated depends on the threshing area. The form of the threshing bar is related to the impact area, thereby allowing the threshing material impact force to be determined. Thus, considering the cross-sectional area, the threshing bars were designed as shown in Figure 1.

As shown in Figure 1, three types of bars ((A) type-A, (B) type-I, (C) type-L) were designed and developed for

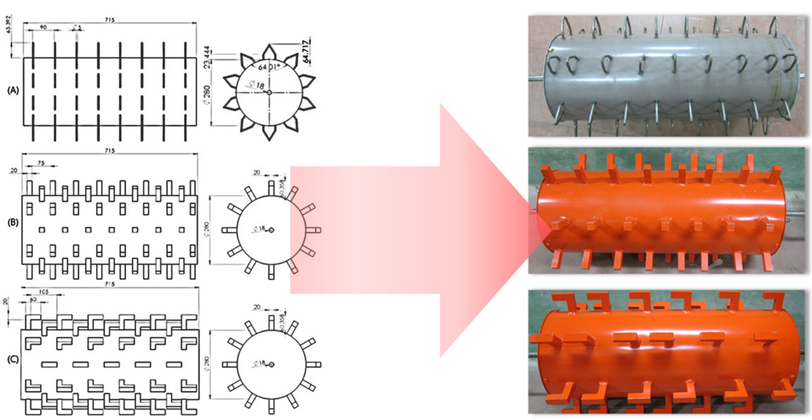

Figure 1. Design of three types ((A) type-A, (B) type-I, (C) type-L) of threshing bars and actual threshing cylinders with bars.

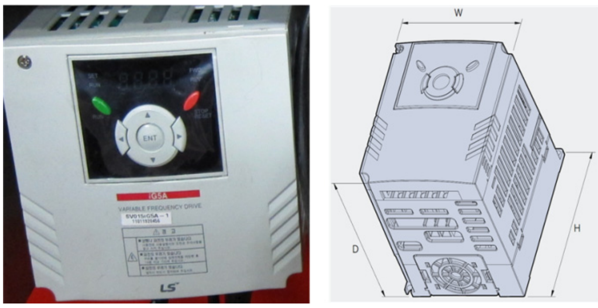

Figure 2. Inverter for control of cylinder rotation.

Table 1. Specifications of inverter.

Model	SV015iG5A-1 (LG, Korea)
Size (mm × mm × mm)	176 × 147 × 45
Weight (kg)	1.8
Power (kW)	1.5
Current (A)	12
Voltage (V)	250

the test. The impacting area, sorted from high to low, is (C), (B), and (A).

Control system of cylinder rotating speed

According to Equation 1, the threshing energy can be determined by the angular velocity of the cylinder. In this experiment the cylinder was installed with an inverter (see Figure 2), to control the speed of cylinder rotation. The specifications of the inverter are given in Table 1.

Threshing system design

Figure 3 shows the threshing system design. As shown in the figure, the cylinder with three different bars was developed based on the conventional threshing machine using commercial computer software.

At each cylinder, three different types of bar were also designed and attached on the cylinder.

To measure threshing performance, a loading chamber was designed at the bottom of the thresher (Figure 3). After threshing, the sesame seeds and peel separated from the pod and fell freely into the loading chamber.

The threshing performance was evaluated in terms of the ratio of unthreshed sesame to threshed sesame. The ratio of unthreshed sesame is given in equation (2). In addition, the moisture content of the sesame was measured by the dry oven method (ASAE standards S358.2, 1998), at 103°C for 24 h at 25 g.

$$U(\%) = \frac{M_u}{M_t + M_u} \times 100 \qquad (2)$$

Where, M_t: The mass of the threshed sesame (g)
M_u : The mass of the unthreshed sesame (g)

In order to measure the ratio of unthreshed sesame for the threshing system with each designed bar (three types), and at three levels (300, 400, and 500 rpm) of cylinder rotating speed, the test was repeated three times.

Results and discussion

The average moisture content of the sesame used in this experiment was 16.7% (d.b), and 16.1% (d.b) for the conventional sesame (Hwangbaek) and the shatter-resistant sesame (KS11), respectively.

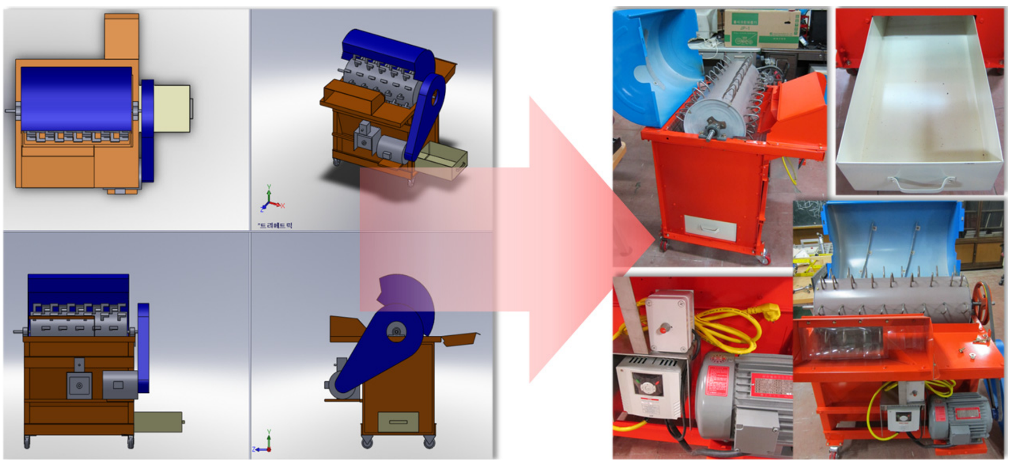

Figure 3. Threshing system design and development.

Table 2. Specifications of thresher system.

Thresher	Length (mm)	922
	Width (mm)	1064
	Height (mm)	970
Cylinder	Width (mm)	715
	Diameter (mm)	280
Loading device	Length (mm)	830
	Width (mm)	300
	Height (mm)	140
Total weight (kg)		280
Power source		Electric motor

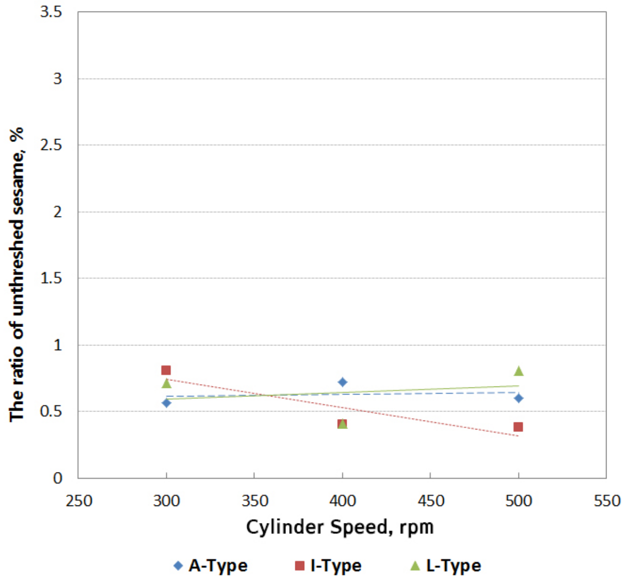

Figure 4. Ratio of unthreshed sesame according to bar type and cylinder rotating speed (conventional sesame: Hwangbaek).

The moisture content of the sesame is the material factor for the thresher. However, in this study only one level of moisture content for each sesame was tested, because this study focused on mechanical and systemic factors.

In the case of conventional sesame, the ratio of unthreshed sesame did not show significant difference with either bar type or cylinder rotating speed (see Figure 4). Conventional sesame is easily threshed without any impact so the loss rate of sesame during the harvesting, drying, and conveying processes was high. This is the reason shatter-resistant sesame was developed. However, in the case of shatter resistance sesame, the ratio of unthreshed sesame decreased with increasing cylinder rotating speed, for all three types of bar.

As seen in Figure 5, the A-type bar (conventional tooth)

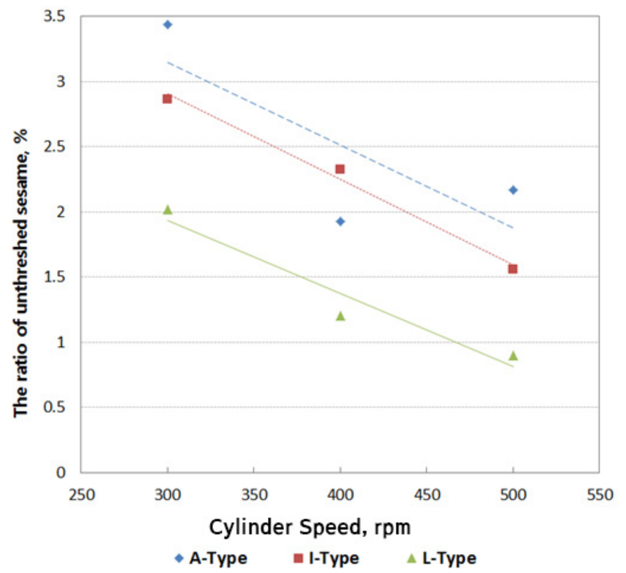

Figure 5. Ratio of unthreshed sesame according to bar type and cylinder rotating speed (shatter resistant sesame: KS11).

showed a higher value than other types bar. The impact area of the A-type bar is smaller than for the other bars, so the kinetic energy of the A-type bar was low, in accordance with energy Equation (1).

The results for the A-type bar also applied to the I-type bar (which has the second highest impact area) result.

Considering the bar type alone, the ratio of unthreshed shatter-resistant sesame for the L-type bar showed the best result.

Conclusions

A threshing system for shatter-resistant sesame was designed and developed in this study.

Two types of sesame (shatter-resistant and conventional) were tested using the developed sesame threshing system. Three types of serrated bars (conventional A-type bar, I-type bar, and L-type bar) were designed and evaluated through a performance test, in terms of the ratio of unthreshed sesame, for both types of sesame.

In the case of conventional sesame, the ratio of unthreshed sesame did not show a large amount of difference in relation to bar type and cylinder rotation speed. Because of the easy separation nature of conventional sesame, it is not suitable for using the new thresher.

For shatter-resistant sesame, however, the ratio of unthreshed sesame decreased with increased cylinder rotating speed for all three types of bar. The L-type serrated bar (blade) showed the best results: 0.9% at 500 rpm cylinder speed.

As the impact area of the bar increased, the kinetic energy of the cylinder also increased. As a result, the unthreshed ratio of sesame decreased. The rotation speed of the cylinder showed the same result in the energy equation.

These results are useful for the construction and utilization of the shatter-resistant sesame threshing harvester.

However, further studies are needed to determine the effect of sesame moisture content, crack ration of threshed sesame, etc.

Conflict of Interest

The authors have no conflicting financial or other interests.

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