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Separation Characteristic of Shatter Resistant Sesame After Threshing

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Abstract

Purpose: This study set out to develop a machine for separating shatter-resistant sesame after threshing. **Methods:** Three grades of sieve and different blower speeds were tested for a separation system that had been designed specifically for shatter-resistant sesame. Performance tests were run to evaluate the sieve and blower systems in terms of the sesame separation and loss ratios. **Results:** Tests of the first separation stage using the sieve system revealed the optimum sieve perforation size to be 5 mm. Tests of the second separation stage using the blower system identified the optimum blower speed as being 220 rpm. The optimum separation and loss ratios, of 96.5% and 3.5%, respectively, were obtained at a blower speed of 220 rpm. **Conclusions:** These results will be useful for the design, construction, and operation of threshing harvesters. For shatter-resistant sesame, an optimum blower speed of 220 rpm was identified.

Keywords: Harvester, Separation, Sesame, Shatter-resistance, Thresher

Introduction

Sesame is a popular oil seed in the Far East, especially in Korea. Sesame seed consists of oil (about 50%), protein (22%), carbohydrates, vitamins, calcium, and phosphorus (Kim et al., 2004). However, even though sesame is the most important oil crop in Korea, the country is heavily dependent on imports, which account for about 70% of the nation's sesame consumption. Korea's sesame market is characterized by high levels of consumption, but low production rates, and therefore a major dependence on imports.

Many farmers want to cultivate sesame because it is a highly profitable crop but, in order to reduce the cost of production, the use of mechanization is essential (Lee and Kim, 2007, 2009[ab]). Within the cultivation process, the forming of a ridge, mulching, and seeding have all been mechanized, but weeding and harvesting operations have been done entirely by hand (Yilmaz et al., 2008). In addition, the fall harvest of sesame tends to fall during the rainy season, so large amounts of sesame are likely to be lost during the harvesting process.

Thus, the mechanization of the harvesting process is essential to reducing production costs. To enable the mechanization of sesame harvesting, the sesame was first bred to be shatter resistant, and these new shatter-resistant varieties were then introduced to the farmers.

Many researchers have studied how sesame can be made shatter-resistant, which involves making the pod opening narrower than that of conventional sesame, with seeds that remain in the pod after maturing. Recently developed varieties of shatter-resistant sesame greatly reduce the losses resulting from shattering during harvesting.

In this study, a machine for separating the shatter-resistant sesame after threshing was developed, so that producers could realize savings in both time and labor. This system will not only solve the problems faced by the farmers, but also increase the area that can be given over to sesame production, given these savings in time and labor. To separate the sesame after threshing, a sieve and blower system was designed and then evaluated in terms

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of its output capacity, separation efficiency, and grain loss.

Materials and Methods

Shatter-resistant sesame

Shatter-resistant sesame (KS11) was sown in July 2011, in Suwan, Korea, and then harvested in November of the same year.

Factors affecting separation of shatter-resistant sesame

The performance of the machines used to separate shatter-resistant sesame depends on the threshing degree, which is determined by the amount of sesame being processed, and the rate at which it is fed into the machine. The mechanical aspects of the sesame separation system can be divided into the sieve and blower parts.

Sieve

Figure 1 shows the design of the sieve, the function of which is to eliminate straw and other material (chaff) from the threshed shatter-resistant sesame (first separation). Thus, the sieve perforation size and morphology will have a significant impact on the efficiency. An experiment was performed using three different grades of sieve for the first separation. On average, a sesame seed measures 3 mm in length, 1.2 mm in width, 0.8 mm in thickness, and weighs 2 to 4 g per 1000 seeds. Based on this data, three different grades of sieve were designed with perforations that were 3 mm, 5 mm, and 7 mm in diameter. The thickness of the sieve was 3 mm.

Modification of thresher for use in separation system

A threshing machine (BHD-1300, Buheung Machinery Ltd, Jinju-si, Korea) was modified for this experiment. This machine measures 970 mm in length, 1110 mm in width, and 1090 mm in height. It weighs 132 kg, is designed to rotate at 300 to 400 rpm, and requires a 2-HP power source.

The three different sieves, with different-sized perforations, were installed in the threshing machine.

Blower speed controller

Sesame seeds that have been produced by the first separation are then passed to a second separation process

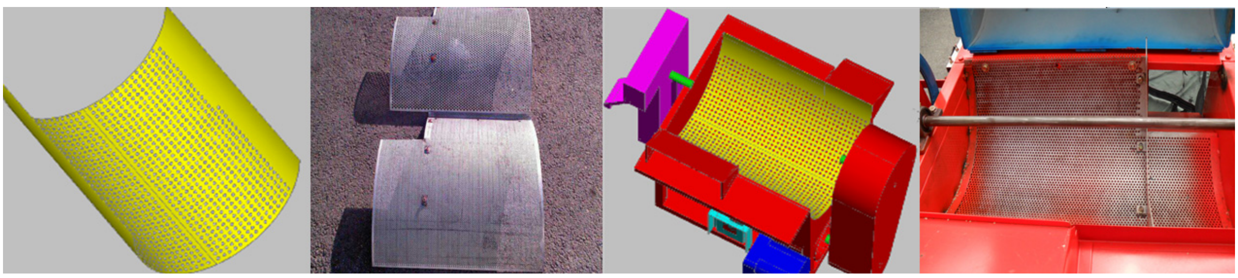


Figure 1. Design of sieve and sieve system installed in thresher without drum.

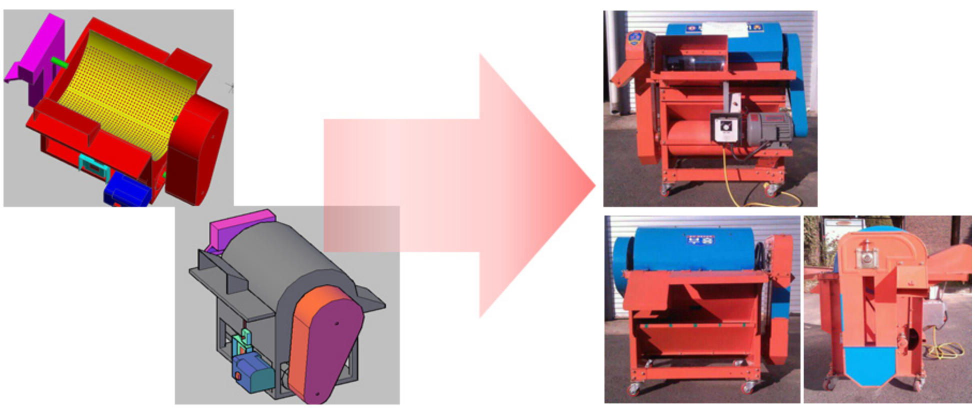


Figure 2. Thresher with inverter for blower speed control.

in which derivatives and dirt are removed. To enable this, a variable-speed blower was installed, together with an inverter (Figure 2).

The sesame seeds and chaff that have passed through the first separation process pass through the sieve and free-fall under the influence of gravity. As they fall, the chaff is eliminated by the airflow produced by the blower.

Figure 3 shows the design of the blower system installed in the thresher. The arrows represent the direction of the airflow generated by the blower, while the black circle is the auger that removes the separated sesame.

In Figure 3, the blower fan has a 10 cm radius, and its horizontal length is equal to the length of the threshing machine. In this process, the relatively light chaff and other material is blown out of the thresher and the separated sesame falls to the bottom of the machine where it is carried away by the auger. The airflow, which is proportional to the rotational speed of the blower fan, is controlled by the inverter. These first-separation (sieve) and second-separation (blower) systems were built into the modified thresher.

Experimental methods

Threshed shatter-resistant sesame produced with an L-type toothed drum rotating at 500 rpm was used to determine the optimum size of the sieve perforations for the first separation, with the feed rate and separation being tested for sieves with three different perforation sizes.

The threshed sesame output by the first separation system was fed to the second separation system, in which the blower speed was varied to find the optimum airflow for the separation. Preliminary testing produced four candidate blower speeds, specifically, 220, 230, 240, and 250 rpm. The moisture content of the sesame was determined by a standard oven-drying method (ASAE, 1983). The preliminary tests were performed with sesame seed only, in order to determine the optimum blower speed without the presence of any chaff.

For each speed, the weights of the separated sesame and blown-out (unseparated) sesame were measured and the separation and loss rates were calculated by using the equations below:

Figure 3. Design of blower system in thresher.

(a) (b) (c)

Figure 4. Sesame separation involving (a) feeding, (b) blowing, and (c) collecting.

$$S(\%) = \frac{M_s}{M_S + M_{us}} \times 100 \quad (1)$$

$$L(\%) = \frac{M_{us}}{M_s + M_{us}} \times 100 \quad (2)$$

where S: separation ratio (%)
L: loss ratio (%)
M_s: mass of separated sesame (g)
M_{us}: mass of unseparated sesame (g)

Figure 4 shows the sesame separation process, which involves feeding, blowing, and collecting. The threshed sesame (sesame plus chaff) produced by an L-type toothed drum was fed directly to the sieve. Any unseparated sesame blown out from the thresher was collected behind the thresher while the separated sesame was carried out by the auger. All of the tests were repeated three times and then the results were averaged.

Results and Discussion

The average moisture content of the sesame used in this experiment was 16.1% (dry basis). Tests to determine the optimum sieve size showed that the 5-mm sieve produced the best feed rate; the 3- and 7-mm sieves had on adverse effect on the thresher feed rate. With the 3-mm sieve, it took more time to feed the sesame being separated. On the other hand, the feed rate was very high with the 7-mm sieve but the amount of separated chaff also increased.

The preliminary results for the optimum blower speed are listed in Table 1. From the table it can be seen that, as the blower speed increases from 240 rpm to 250 rpm, the weight of the unseparated sesame increased from 6.7 g to 16 g. Therefore, considering the sesame loss, the speed of the blower was set to 240 rpm for the sesame separation test.

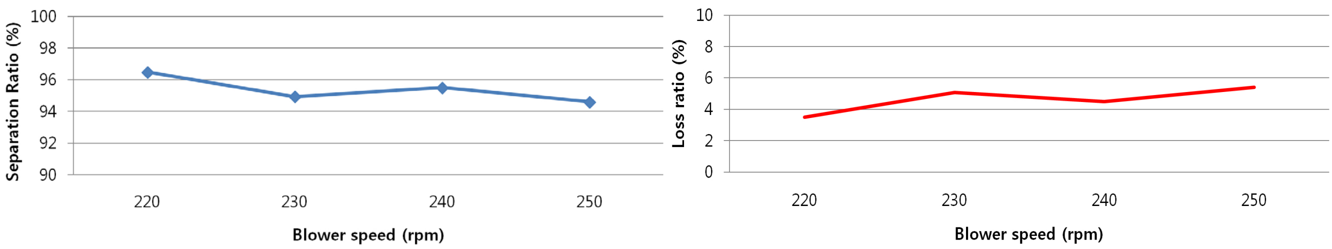
The sesame separation results for different blower speeds

Table 1. Preliminary sesame separation results for a range of blower speeds

Blower speed (rpm)	Unseparated sesame (g)	Separated sesame (kg)	Separation ratio (%)
300	79.50	2.08	97.35
250	16.00	2.78	99.47
240	6.70	2.85	99.78
220	5.60	2.84	99.81
200	3.50	2.70	99.88
180	1.86	2.55	99.94

Table 2. Sesame separation results for a range of blower speeds

Blower speed (rpm)	Separated sesame		Unseparated sesame		Separation ratio (%)	Loss ratio (%)
	Sesame (g)	Chaff (g)	Sesame (g)	Chaff (g)		
220	340.7	7.1	12.4	63.6	96.5	3.5
230	334.5	7.7	17.8	71.2	94.9	5.1
240	334.3	10.9	15.7	65.6	95.5	4.5
250	332.9	9.2	18.9	55.9	94.6	5.4



(a) Separation ratio (b) Loss ratio

Figure 5. Separation and loss ratios of the system over a range of blower speeds.

are listed in Table 2. The separation and loss ratios for four different blower speeds did not differ significantly, with the values ranging from 94.6% to 96.5%, and 3.5% to 5.4%, respectively. However, when the blower speed was 220 rpm, the highest separation ratio (96.5%)/ lowest loss ratio (3.5%) were achieved.

Figure 5 shows the separation and loss ratios for the different blower speeds. In Figure 5(a) a higher value indicates the better operation of the separation system, such that a blower speed of 220 rpm is optimum. For the loss ratio shown in Figure 5(b), a lower value is better and, again, a blower speed of 220 rpm is the optimum value.

Conclusions

A system for separating shatter-resistant sesame after threshing was developed. To separate the sesame, a sieve and blower system was designed and evaluated in terms of feed rate, separation efficiency (separation ratio), and grain loss (loss ratio).

For the first separation using the sieve system, the optimum size of the sieve perforations was found to be 5 mm in diameter. If the perforation size was increased, the amount of chaff mixed with the sesame also increased. On the other hand, if the perforation size was decreased, the feed rate also decreased.

For the second separation using the blower system, the optimum blower speed was found to be 220 rpm, at which the optimum separation and loss ratios, at 96.5% and 3.5%, respectively, were attained.

The results of this work will be useful to the design, construction, and operation of a shatter-resistant sesame threshing harvester.

Conflicts of Interest

The author has no conflicting financial or other interests.

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