Study on machine-crop parameters of cylinder threshers for cumin threshing

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Abstract: Prior to developing a cumin thresher, the efficiency factors of cumin threshing was investigated. The effect of thresher variables including the moisture content, cylinder type and cylinder speed, feed rate and concave clearance on weight percentage of separated seeds, shattered stems and damaged seeds were studied in this research. The results showed that as moisture content increased from 7% to 13%, separated seed and damaged seed decreased from 92.8% to 90.4% and from 10.1% to 7.6%, respectively. However, increasing cylinder speed from 12.8 to 16.5 m/s, increased the percentage of separated seed, shattered stems and damaged seed. The cylinder type did not have significant effect on weight percentage of separated seed, while it had a significant effect on shattered stems and damaged seeds. It was concluded that the rub bar cylinder was better than the rasp bar cylinder. Thus, the rub bar cylinder, 16.5 m/s cylinder speed and 7% grain moisture content were the most suitable conditions for cumin threshing.

Keywords: thresher, cumin, moisture content, cylinder type, cylinder speed, feed rate, concave clearance

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1 Introduction

The cumin (*Cuminum cyminum Linn.*) is an annual plant and suitable for dry and semi-dry conditions. Cumin belongs to *Apiaceae* family and is generally consumed in the medicinal industry. A cumin seed is 5-6 mm long and 1.5-2 mm in diameter. The shape of a cumin seed is spindly and it comprised of two parts of mericarp. Cumin seeds are located on thin branches (Figure 1). (Kaafi et al., 2002)

In conventional farming in Iran, cumin is harvested in two stages, which prevents seeds shedding. Firstly, cumin bushes are picked up using hand sickle or scythe. Then after drying, cumin bushes are threshed by beating with a stick, tramping with animals, or driving over them with a small tractor. This harvesting method is time consuming and labor intensive. In addition, it is incomplete threshing with crop loss and poor quality results. The main aim of this research was to investigate effects of machinery parameters and moisture content on cumin threshing in order to develop a cumin threshing machine.

a. Cumin seed amid and two mericarps both sides b. Cumin seeds on thin branches

Figure 1 Photos of Cumin plant and seeds

Vejasit and Salokhe (2006) studied the effects of machine-crop variables on the performance an axial flow thresher for threshing soybeans. Test results indicated that the threshing efficiency varied from 98% to 100%.

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Damaged grain and grain loss were less than 1% for 600 r/min cylinder speeds, 540 kg(plant)/h feed rate with 14.3% seed moisture content, whereas it was less than 1.5% for 700 r/min, 720 kg (plant)/h with 22.8% (w.b.). The best combination of feed rate and cylinder speed at 14.3% moisture content was 600 to 700 r/min (13.2 to 15.4 m/s) and 720 kg (plant)/h.

Rani et al. (2001) studied the effects of moisture content and cylinder speed on threshing chickpea. They reported that the maximum threshing efficiency was 97.2% at 8.9% seed moisture content with 10.1 m/s cylinder speed. Wacker (2003) studied the effects of several wheat varieties on the performance of threshing. The results showed that moisture content, speed cylinder and concave clearance (space between concave and cylinder) all had an effect on wheat threshing. Ajav and Adejumo (2005) evaluated effects of moisture content, concave clearance, cylinder speed and feed rate on threshing performance and damaged okra seeds. They reported that moisture content had a significant effect on threshing performance and seed germination. The effect of cylinder speed was significant on threshing performance alone. Khazaee (2002) reported that speed cylinder and moisture content had a significant effect on chickpea threshing efficiency and damaged grain percent, but pea variety did not have a significant effect on threshing efficiency and damaged grain percentage.

2 Materials and methods

This study was carried out at Khorasan Agricultural and Natural Resource Research Center, Mashhad, Iran. The threshing unit had been designed and fabricated (Figure 2). The thresher was equipped with a cylinder 350 mm in diameter, which allowed the possibility of fixing two types of bar (rub and rasp). Two electric motors were used for cylinder and feed belt power. A digital inverter was provided to control the speed of cylinder electric motor. A digital tachometer (Dt-838 model) was used for measuring rotational speed. Changing of belt velocity was accomplished with a mechanical gearbox that caused feed rate to change. Concave clearance was changeable from zero to 20 mm by the lever handle. Six rub bars or rasp bars were mounted on the cylinder. Rasp bars were the same as commercial combine bars with 400 mm long. Rub bars were constructed from two steel plates (400 mm×50 mm) to which were fixed a rubber plate (400 mm×70 mm) (Figure 3). Three bars with 3 mm thickness and (400 mm×5 mm) dimension were mounted on concave.

Figure 2 Testing cumin threshing unit

a. Rub bar

b. Rasp bar

Figure 3 Diagram of rub bar and rasp bar

In this study five factors were considered: cylinder speed (three levels: 12.8, 16.5 and 22 m/s), feed rate (two levels: 500 and 750 kg (plant)/h/m), concave clearance (two levels: 5 and 10 mm), cylinder type (two levels: rub bar and rasp bar) and moisture content (two levels: 7% and 13% (wet basis)). The rotational speeds of thresher cylinder were 700, 900 and 1200 rpm corresponding to 12.8, 16.5 and 22 m/s peripherial speeds respectively, according to the 350 mm diameter cylinder. Experiments were performed as completely randomized block design with three replications.

The cumin bushes were harvested by hand from farms in Khorasan Province, one of the main producing provinces in Iran, with an annual production of 5455 tons cumin seeds and a yield of 467 kg/ha (Anon., 2006).

The moisture content of the cumin bushes was determined by the following equation (ASAE, 1999):

$$M_c = \frac{m_t - m_0}{m_t} \times 100 \qquad (6)$$

Where, MRR_c is initial moisture content, (% wet basis); m_t (g)
is weight of the wet cumin bushes at initial moisture content; and m_0 (g) *is* defined as the weight of the dried cumin bushes.

Samples of cumin bushes (3 kg) were threshed, then seeds were separated from straw using hand sieve. Weight percentage of separated seeds, stems with 5-50 mm long (shattered stems) and damaged seeds were measured, and treated as dependent variables.

Statistical analysis was done on randomized complete block design applying the analysis of variance (ANOVA) using SPSS 13 software. Duncan's multiple ranges test was utilized to separate means at a 5% level of significance.

3 Results and Discussion

Variance analysis of data shown in Table 1 indicates that moisture content and concave clearance created a significant effect on weight percentage of separated seeds and damaged seeds (P<0.05). Cylinder type had a significant effect on shattered stems and damaged seeds. Test results showed that the cylinder speed had a significant effect on all characteristics and the effects of feed rate on separated seeds were significant.

According to Table 1, the interaction of cylinder type × cylinder speed was significant on damaged seeds. Based on the statistical analyses, the interaction of concave clearance × feed rate and moisture content × cylinder speed × concave clearance were significant at 5% level on separated seeds and damaged seeds.

Table 1 ANOVA of threshing factors on characteristics of threshed cumin seeds (Mean of squares)

Variation source	DF	Separated seeds/%	Shattered stems/%	Damaged seeds/%
Treatment	47	413784.17**	2291.49**	4203.76**
Moisture content	1	48.04*	13.07 ns	155.02*
Cylinder type	1	2.75 ns	27.77*	25.50*
Concave clearance	1	65.43*	19.55 ns	26.34*
Cylinder speed	2	50.14*	29.54*	31.64*
Feed rate	1	26.73*	0.628 ns	4.64 ns
Cylinder type × cylinder speed	2	3.28 ns	4.94 ns	28.55*
Concave clearance × feed rate	1	44.62*	3.77 ns	31.64*
Moisture content × cylinder speed × concave clearance	2	58.46*	14.56 ns	44.11*
Error	96	10.09	13.56	3.53

Note: ns: Corresponding to no significant difference; * corresponding to significant difference at P=0.05; ** corresponding to significant difference at P=0.01.

3.1 Cylinder speed

As was given in Table 2, separated seeds values were 91.3%, 92.9% and 90.1% at 12.8, 16.5 and 22 m/s cylinder speed, respectively. There was no significant difference between 12.8 and 16.5 m/s cylinder speed (P<0.05), but cylinder speed of 22 m/s had significantly lower separated seeds, and higher shattered stems than the two lower cylinder speeds, and significantly higher damaged seeds than the lowest cylinder speed. The weight percentage of separated seeds increased as cylinder speed increased from 12.8 to 16.5 m/s (700 to 900 RPM). This conclusion was consistent with the findings of Vejasit and Salokhe (2006), who reported the threshing efficiency increased as cylinder speed increased from 600 to 700 RPM for threshing soybeans. Contrary to expectations, the increasing of cylinder speed to 22 m/s resulted in decreasing of separated seeds, because the bushes were ejected from thresher at high speed.

According to Table 2, the weight percentage of shattered stems and damaged seeds increased with the increasing of cylinder speed. Khazaei (2002) documented the latter result.

Table 2 Means comparison of characteristics in different variations

Factors	Factor levels	Separated seeds/%	Shattered stems/%	Damaged seeds/%
	12.8	91.3 a	5.9 a	8.5 a
Cylinder speed/m · s^{-1}	16.5	92.9 a	6.3 a	9.2 ab
	22	90.1 b	8.5 b	9.5 b
Moisture content/%	7	92.8 a	7.4 a	10.1 a
	13	90.4 b	6.4 a	7.6 b
Cylinder type	Rasp bar	92.6 a	8.2 a	9.5 a
	Rub bar	93.1 a	6.0 b	8.3 b
Concave clearance/mm	5	94.0 a	7.5 a	10.0 a
	10	91.7 b	6.3 a	8.6 b
Feed rate /kg · h^{-1} · m^{-1}	500	93.2 a	6.8 a	9.1 a
	750	91.9 b	7.0 a	9.2 a

Note: Means for the same factor and in the same column flowed followed by the same letter are not significantly different (P<0.05) according to Duncan's Multiple ranges Test.

3.2 Moisture content

Considering the values presented in Table 2, the weight percentage of separated seeds decreased as seed moisture content increased. In addition, the weight percentage of damaged seeds decreased from 10.1% to 7.6% as the moisture content increased from 7% to 13%. This is in agreement with Ajav and Adejumo (2005), who reported that the seed loss decreases significantly with an increase in moisture content.

3.3 Cylinder type

Cylinder type did not have significant effects on weight percentage of separated seeds, but there were significant effects on weight percentage of shattered stems and the damaged seeds (Table 1). The damaged seeds percentage for rasp bar was higher than rub bar cylinder (Figure 4). This indicates that the rasp bar cylinder provides more intensive and aggressive threshing of the bushes than rub bar cylinder. Rubber bars separated seeds from bushes using rubbing and stroking impact function happened with the increasing in cylinder speed up to 22 m/s. The rubber plates have a smoother surface than the steel rasp bar so the impact is not as strong as the steel rasp bar. Hence, the damaged seeds percentage is lower with the rub bar than the rasp bar cylinder. It proves that the rub bar is better than rasp bar cylinder for cumin threshing. As is shown in Figure 4, there was a trend for increase in damaged seeds with the increasing speed of cylinder from 12.8 to 22 m/s for both cylinder types.

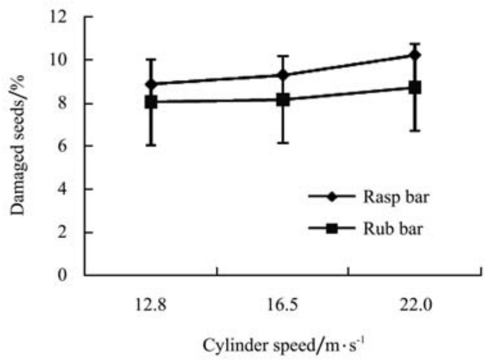

Figure 4 Combination effects of cylinder speed and cylinder type on the damaged seeds percentage

3.4 Feed rate and concave clearance

The effect of feed rate on threshing performance was determined for 500 and 750 kg/h/m. Separated seeds percentage decreased as feed rate increased (Table 2). Separated seeds percentage was 91.9% at 750 kg/h/m feed rate which was significantly higher than the separated seeds percentage at 500 kg/h/m feed rate. This might be attributed to the fact that at higher feed rate, cumin bushes were compressed and did not completely contact with the cylinder bars.

The effect of concave clearance on threshing performance was determined for clearances of 5 and 10 mm. As concave clearance increased, the percentage of separated seeds, shattered stems and damaged seeds decreased. This is in agreement with Wacker (2003) who reported a decrease in damaged seeds percentage of wheat for a wide concave clearance. As is shown in Table 2, at 5 mm concave clearance, separated seeds, shattered stems and damaged seeds percentage were 94.0%, 7.5% and 10.0%, respectively. Nevertheless, at 10 mm concave clearance, they were 91.7%, 6.3% and 8.6%, respectively.

Investigation of the combined effects of concave clearance and feed rate on damaged seeds percentage showed that, feed rate levels had significant and no significant effects at 5 and 10 mm concave clearances respectively (P<0.05) (Table 3). The most and the least difference in separated seeds percentage between 5 and 10 mm concave clearances where found to be at 500 and 750 kg/h/m feed rate respectively (Table 3).

Table 3 Means of percent separated seeds and percent damaged seeds at different combinations of feed rate and concave clearance

Feed rate /kg·h^{-1}·m^{-1}	Separated seeds/%		Damaged seeds/%	
	concave clearance/mm		concave clearance/mm	
	5	10	5	10
500	96.7 a	89.8 b	9.9 a	8.4 b
750	91.4 c	92.5 d	10.2 c	8.1 b

Note: The means followed by the same letter are not significantly different (P<0.05) according to Duncan's Multiple ranges Test.

Investigation of the combined effects of moisture content, concave clearance and cylinder speed showed that the highest difference in damaged seeds percentage among different levels of concave clearance was related to the 16.5 m/s cylinder speed under 7% moisture content (Table 4), while in other cylinder speed categories, there was no significant difference among different levels of concave clearance (P<0.05). The effect of concave clearance was significant on separated seed percentage at 13% moisture content (Table 4).

Table 4 Means of percent separated seeds and damaged seeds at different combinations of cylinder speed, concave clearance and moisture content

Cylinder Speed /m·s^{-1}	concave clearance /mm	Separated seeds/%		Damaged seeds/%	
		Moisture content		Moisture content	
		7%	13%	7%	13%
12.8	5	93.5 a	91.3 a	9.9 ab	8.4 b
	10	92.0 a	88.5 b	8.1 b	7.7 b
16.5	5	96.2 a	92.3 a	10.3 ac	8.8 b
	10	91.2 a	89.7 b	8.9 b	8.1 b
22	5	90.4 ab	90.1 ab	11.7 c	9.7 ab
	10	89.4 b	90.5 ab	9.5 ab	8.1 b

Note: The means of each characteristics followed by the same letter are not significantly different (P<0.05) according to Duncan's Multiple ranges Test.

4 Conclusions

Based on this research, the following conclusions can be drawn:

The rub bar cylinder damaged seeds and shattered stems less than the rasp bar cylinder. The rubber plates have a smoother surface than the steel rasp bar, so the impact is not as strong as the steel rasp bar. Therefore, it is recommended that the rub bar cylinder be used for developing a threshing unit of cumin combine harvester.

The threshing performance was better at 7% than at 13% moisture content.

Results showed that 16.5 m/s cylinder speed was better than 12.8 and 22 m/s at 7% moisture content. Thus, the recommendations for the design of cumin combine harvester, the cylinder speed should be 16.5 m/s for efficient harvesting.

The separated seeds percentage found to be highest value (96.7%) for 5 mm concave clearance and 500 kg/h/m feed rate.

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