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Performance evaluation of developed reciprocating type cumin cleaner cum grader

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■ **ABSTRACT :** India is famous for its pet name in the world of agricultural as the 'home of spices'. India grows 47 out of 70 varieties of spices grown in different parts of the world. Cumin seeds it comes from the field contain foreign matter like weed seeds, stems, leaves, broken seeds, stones, dirt, etc. These foreign matters must be removed to increase quality of seed in the market, storage period of seed, cost of selling and net income to the farmers as well as sellers and to perform different kinds of post harvest operations. Cleaning and grading of cumin in the marketing yard is time consuming and laborious operation because large quantity is to be handled. Some of the big traders used mechanical cleaners and graders, but the initial investment required in the purchasing of such machinery is quite high. Efforts were made to develop a low cost machine that can clean and grade the seed of cumin and can be utilized for the above operation at low investment. Effects of different machine operating parameters on its performance *i.e.* feed rate, speed and screen slope were evaluated for cleaning efficiency. For getting best cleaning efficiency and low power consumption, the machine should be operated at 50 kg/h feed rate, 150 rpm and 7-degree slope. The cost of cleaning is Rs. 0.31/-

■ **KEY WORDS :** Cumin, Cleaner cum grader, Cleaning efficiency, Power consumption

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India is one of the major spices producing and exporting countries of the world. Cumin (*Cuminum cyminum* L.) is mainly grown in India in the states of Rajasthan and Gujarat. In India, during the year 2009-10, the area under cumin cultivation was about 593980 ha and producing 394330 tons cumin seeds. In Gujarat, the production of cumin was about 338192 tons over an area of 372584 ha during the year 2012-13 (Anonymous, 2013). An estimate shows that the cumin seeds received at the marketing yard from the field contain average 20-25 per cent impurities. These impurities must be removed to increase quality of seed in the market, storage period of grain, cost of selling and net income to the farmers as well as sellers and to perform different kinds of post harvest operations (Krishnamurthy and Ramakumar, 1984). Cleaning and grading of cumin in the marketing yard is very intensive operation. It is also very laborious and time consuming because large quantity is to be handled.

Presently, in the marketing yard a single blower followed by screening through an inclined sieve is the system prevailing for the cleaning of cumin seed, which is quite inefficient and labour intensive. Some of the big traders also use mechanical cleaners and graders. The capacity of such machinery is quite high and the initial investment required in the purchasing of such machinery is also more. Some research on cleaner cum grader of different seeds has been done. Saurabh (1990) developed

a cleaner-cum-grader suitable for spices like cumin seeds, funnel seeds, etc. having vibratory screen. Kachru and Sahay (1990) tested a medium capacity pedal-cum-power-operated grain cleaner for various seeds. Hall (1991) measured the cleaner response for different parameters.

Vishwanathan *et al.* (1994) developed a rotary sieve type cleaner-cum-grader suitable for small size impurities. Srivastava (1996) developed a mechanical rotary double screen cleaner-cum-grader suitable for cumin seed to reduce the drudgery of manual cleaning. In order to improve the cumin processing technique and mechanize the operations, an attempt has been made to design and develop suitable cumin cleaner cum grader. Thus, a low cost machine that clean and grade the seed of cumin and can be utilized for the above operation at low investment. It is expected that the outcome of the research work would be directly useful to the farmers and small traders. By introducing cleaner at farmer's level the margin of profit to the farmer's will be more as it avoids further grading at disposal point.

METHODOLOGY

Based on the information available, the survey of Jeera Mandi at Unjha, dist. Meshana, Gujarat was carried out and also discussion made with the cumin processors for the development of reciprocating type cumin cleaner cum grader. The major components were feed hopper, sieve box, blower and the power transmission unit to provide reciprocating motion to the sieve box and arrangement of collection of clean cumin seeds.

Machine components :

Feed hopper :

A prismoidal shaped hopper of 15 kg holding capacity with a length of 710 mm and over all height of 200 mm was fabricated with 22-gauge GI sheet. A sliding gate was provided at the bottom of the feed hopper to regulate the flow of cumin seeds from feed hopper to sieve box. The hopper was mounted on mild steel frame (35 x 35 x 3 mm) having overall dimensions of 1600 x 1000 x 560 mm.

Sieve box :

A rectangular shaped sieve box of 800 mm length, 600 mm width and 450 mm height was fabricated from 20 gauge GI sheets. In order to increase the rigidity of the sieve box, an angle iron plate of 35 x 3 mm size was provided on outside of the sieve box. The sieve box was mounted from outside at both ends on four rollers bearings which were mounted at the sides of the sieve box to guide the reciprocation of the sieve box at fixed axis. Three galvanized iron screens having mesh openings of 25 mm round holes, 15 mm round hole and 0.490 mm wire mesh were selected for getting 3 grades of cumin. Screens were stitched with the help of wire on an angle iron frame of 20 x 20 x 3 mm dimensions and riveted in the sieve box at certain angle with the aim to provide more time of traveling of cumin on the screens. A slope adjustment screw in the sieve box was provided to adjust the slope of all the screens. Three trapezoidal shaped outlets were also provided at the discharge end of the each screen to collect the material outside the box. The outlets were fabricated from the same material used for the sieve box.

Blower :

The blower was fabricated from the 20-gauge M. S. sheet to provide 4-5 m/s air velocities. Four blades of 410 mm length were fabricated from the 16- gauge M. S. sheet. The diameter of the impeller was 230 mm. The blades were welded together at 90 degree to each other on 20 mm diameter shaft. The diameter of blower casing was 250 mm. The whole assembly was mounted on an angle iron frame (35 x 35 x 3 mm) with the help of the suitable pedestal bearings.

Power transmission unit :

The other end of the machine was connected with the power transmission unit. A 25 mm diameter shaft was housed in two anti friction bearings mounted below the upper shaft of the blower. Step pulleys of different sizes *i.e.* 50-75-100-125 mm diameter were mounted on 25 mm diameter shaft to transmit power from motor to the blower and eccentric unit with the help of V-belts pulleys arrangement. A 300 mm diameter pulley was mounted on the 18 mm diameter shaft to achieve required rpm at the sieve box. To provide the power to the moving parts of the machine, 1 HP electric motor of 1425 rpm was selected.

Frame:

An angle iron frame to support different component of the machine was fabricated using mild steel angle

iron of 35 x 35 x 3 mm size. The overall dimension of the frame was 1600mm long x 560 mm breadth x 1000 mm height. The motor, blower and power transmission unit were suitably fitted at the frame with appropriate base.

The schematic diagram of the developed cumin cleaner cum grader is shown below in Fig. A. The developed reciprocating type cumin cleaner cum grader was set up by assembling the various parts like feed hopper, sieve box, blower and power transmission and drive unit.

Performance evaluation of cleaner cum grader :

Testing of various components of the machine :

The various components of the developed machine were installed on leveled ground. The electric motor was duly fitted with the machine. The preliminary trial runs were made to check the inspection of various components, which include the checking of the proper tension in the belt drive, alignment of the driven and reciprocating shaft, and movement of the cumin seeds through different outlets and movement of the sieve box.

Calibration of feed hopper :

The flow of cumin from the feed hopper was calibrated at different gate opening positions like 3, 5, 7 and 10 mm in order to obtain the required feed rates of 25, 50 75 and 100 kg/h.

Testing parameters :

To study the effects of different operating parameters on the machine performance, the following parameters were selected like independent parameters (Moisture content, feed rate, speed, screen slope) and dependent parameters (cleaning efficiency and power consumption).

Cleaning procedure :

After assembling the machine, various runs were carried out to evaluate different parameters affecting on the performance on the machine. The cumin at the marketing yard contains only 15-25 per cent impurities. However, the cumin procured from the Fareni village of Dhoraji Taluka, Rajkot contained only 10-15 per cent impurities and therefore, calculated amount of small size sand, stone pieces and chaff were added to have a 20 per cent level of impurities in the cumin seed.

A sample of 5000 g of GC-1 variety cumin was taken in the hopper for the experiment. The machine was set at required speed by using appropriate step pulley arrangement and the screens were set at required slope.

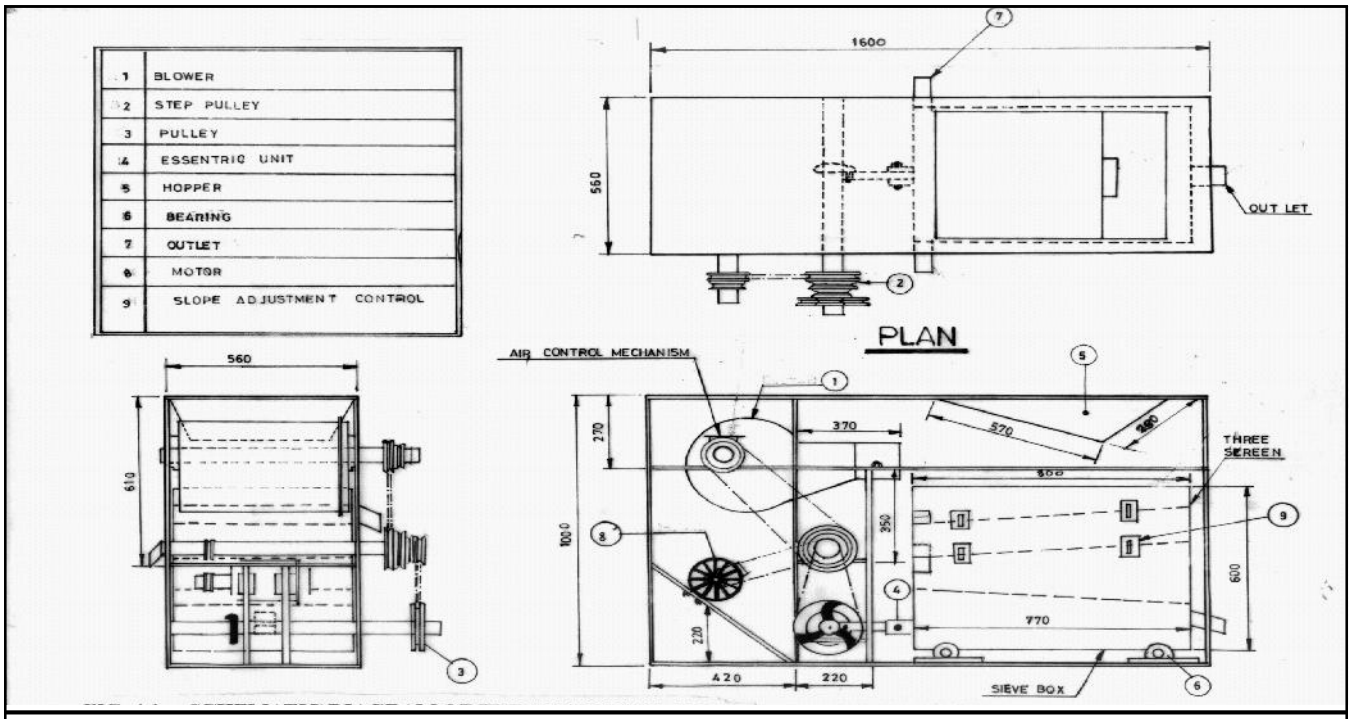

Fig. A : Schematic diagram of developed cumin cleaner cum grader

Blower was also set to a required airflow by opening the shutter to a desired level. When the machine was made ready with the required settings, a plastic container was kept under the three outlets of the machine to collect the different fraction of cumin. The cleaning efficiency of the machine was determined by the using the following equation :

$$\text{Effeciveness of the screen, } E = \frac{(mf - mu)(mo - mf)\, mo\, (1 - mu)}{(mo - mu)^2 (1 - mf)\, mf}$$

where,

E = Effectiveness of the screen

mf = Mass fraction of material in feed

mo = Mass fraction of material in overflow

mu = Mass fraction of material in underflow

The specific power consumed by the machine was computed using the following equation:

$$\text{Specific power consumer} = \frac{(f - i) \times 3600}{t \times F \times E}$$

where,

P = the power consumption, Kwh / kg

f = final energy meter reading, kw

i = initial energy meter reading, kw

t = time for cleaning the sample, sec

F = feed rate, kg/h

RESULTS AND DISCUSSION

The developed cumin cleaner cum grader shown in Fig. 1 was tested for its performance at 4-feed rates, 3-slopes and 1-moisture content. The cumin cleaner cum grader was operated at different speeds of 100, 150 and 200 rpm. The test data were analyzed by using analysis of variance (ANOVA) techniques to determine cleaning efficiency or screen effectiveness at various operating parameters and their interactions.

Fig. 1 : Developed cumin cleaner cum grader

Effect of feed rates and speeds on cleaning efficiency :

The cleaning efficiency of cumin cleaner cum grader may be affected by moisture content, feed rate, speed, slope bed density, particle size and shape. The results of cleaning efficiency of cumin cleaner cum grader at various feed rates and speeds are given in Table 1 and graphically represented in Fig. 2 and 3. Feed rates

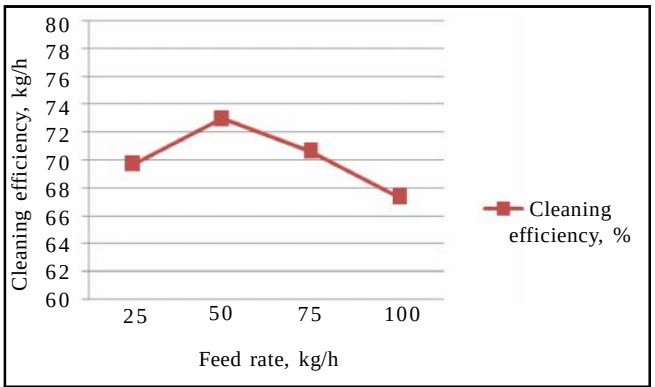

Fig. 2 : Effect of feed rate on cleaning efficiency

Table 1: Effect of feed rates and speed on cleaning efficiency

Speed, rpm	Cleaning efficiency at various feed rate, kg/h				
	25	50	75	100	Mean
100	66.82	70.60	67.73	64.59	67.43
150	71.94	75.40	72.92	68.87	72.28
200	70.31	72.84	71.18	68.48	70.70
Mean	69.69	72.94	70.61	67.31	70.13
SOURCE		S.E.M.		C.D. (P=0.05)	
Feed rate		0.3312		0.9349	
Speed		0.2868		0.8096	
Feed rate and speed		0.5736		NS	

NS= Non-significant

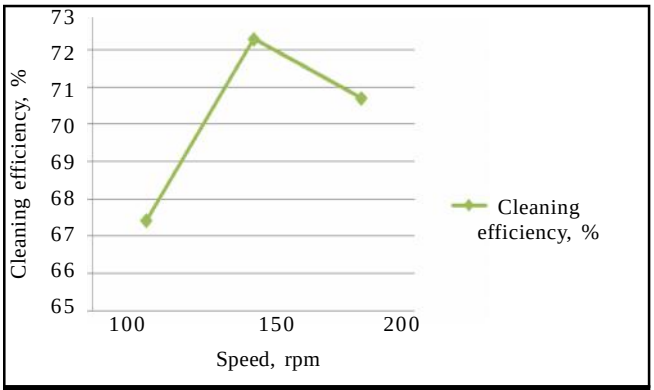

Fig. 3 : Effect of speed on clenaing efficiency

and speeds had significant effect on cleaning efficiency. However, their interaction between feed rates and speeds had non-significant effect on cleaning efficiency.

The mean values of cleaning efficiency at 25, 50, 75 and 100 kg/h feed rates were 69.69, 72.94, 70.61 and 67.31, respectively. From the figure, it is clear that as the feed rate increased from 25 to 50 kg/h, the cleaning efficiency also increased and decreased with further increase in feed rates. The maximum cleaning efficiency was found at 50 kg/h feed rate *i.e.* 75.40 per cent, whereas the minimum cleaning efficiency was found at 100 kg/h *i.e.* 64.59 per cent. The lower cleaning efficiency at higher feed rate may be due to the reason that all the cumin seeds are not getting equal opportunity to pass through the holes of screens provided inside the sieve box as compared to lower feed rate.

The mean values of cleaning efficiency at 100, 150 and 200 rpm speeds were 67.43, 72.28 and 70.70, respectively. The maximum cleaning efficiency 75.40 per cent was found at 150 rpm whereas the minimum cleaning efficiency 64.59 per cent at 100 rpm. The lower cleaning efficiency at higher speed may be due to the reason that all the cumin seeds are not getting sufficient time on the screen and also cumin seeds may be overflowing over the screens and not passing through the holes of the screen. At lower speed the contact area per seed for cleaning will be more as compared to higher speed. The individual effect of feed rate and speed found to be significant at 5 per cent level of significance but their interaction was found to be non- significant at 5 per cent level of significant. The following multiple regression equations of the second order were developed by taking cleaning efficiency as a function of feed rates and speeds;

Cleaning efficiency of cumin cleaner cum grader Z f (feed rates, FR and speed, S)

$$Y = 67.60 - 3.78\times10^{-2}(FR) + 3.27\times10^{-2}(S)$$

(R^2 = 0.027; Non-significant)

where, R = Co-efficient of correlation.

Effect of feed rates and screen slope on cleaning efficiency :

The results of the cleaning efficiency at various feed rates and slopes are given in Table 2 and shown graphically in Fig. 4 and 5. For the feed rates, the similar

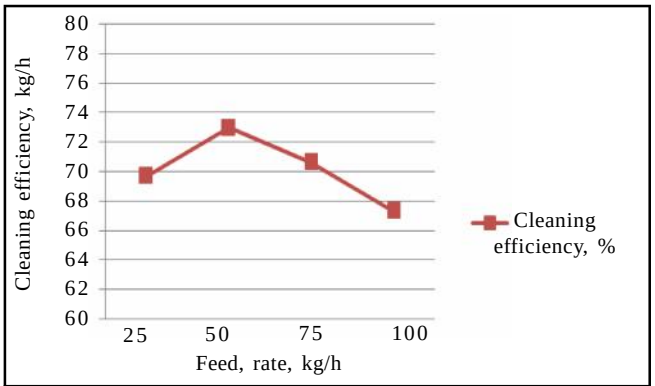

Fig. 4 : Effect of feed rate on clenaing efficiency

Table 2 : Effect of feed rates and screen slope on cleaning efficiency

Screen slope, degree	Cleaning efficiency at various feed rate, kg/h				
	25	50	75	100	Mean
0	64.01	67.55	64.40	59.57	63.88
4	69.95	73.07	71.00	67.85	70.46
7	75.12	78.23	76.43	74.53	76.07
Mean	69.69	72.95	70.61	67.31	70.14
SOURCE		S.E.M.		C.D. (P=0.05)	
Feed rate		0.3312		0.9349	
Screen slope		0.2868		0.8096	
Feed rate and screen slope		0.5736		1.619	

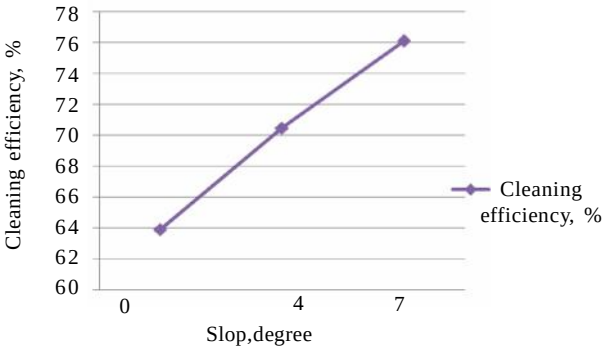

Fig. 5 : Effect of slope on cleaning efficiency

results have been obtained as mentioned earlier.

The mean values of cleaning efficiency at 0, 4 and 7-degree slopes are 63.88, 70.46 and 76.07, respectively. It is clear from the Fig. 5 that, as the slope increased, the cleaning efficiency also increased. The maximum cleaning efficiency 78.23 per cent was found at 7- degree screen slope and the minimum cleaning efficiency 59.57 at 0 degree screen slope. The cleaning efficiency at higher slope may be due to the reason that, at higher slope, cumin seeds slides easily over the screen and passes through the holes which ultimately results in better cleaning efficiency. The individual effect of feed rate and slope was found to be significant and their interaction was also found to be significant at 5 per cent level of significant. The slope is observed as most effective parameter, which influence the cleaning efficiency. The following multiple regression equation of the second order was developed by taking cleaning efficiency as a function of feed rates (FR) and slopes (SS).

Cleaning efficiency of cumin cleaner cum grader Z f (feed rates, F and slopes, SS)

$$Y = 66.14 - 3.78x10^{-2}(FR) + 1.74(SS)$$

(R^2= 0.720; Significant)

Effect of speed and screen slope on cleaning efficiency :

Table 3 gives the cleaning efficiency of cumin cleaner cum grader at various speeds and slopes. For the speeds and slopes, the similar results have been obtained as described earlier and shown graphically in Fig. 6 and 7. The individual effect of speed and slope was found to be significant and their interaction was also found to be significant at 5 per cent level of significant.

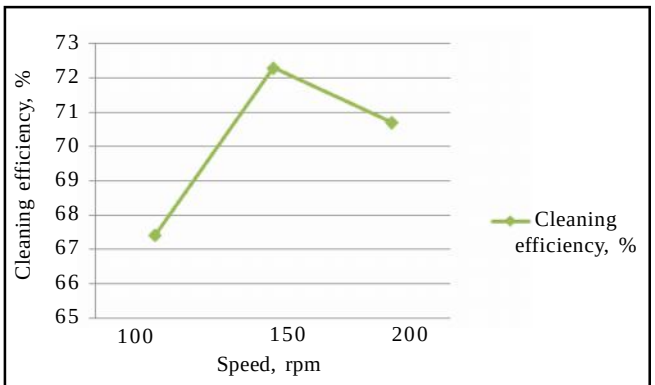

Fig. 6 : Effect of speed on cleaning efficiency

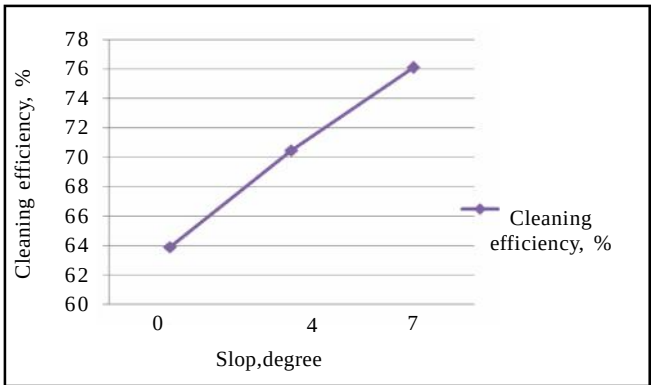

Fig. 7 : Effect of slope on cleaning efficiency

Table 3: Effect of speed and screen slope on cleaning efficiency

Screen slope, degree	Cleaning efficiency at various screen speed, rpm			
	100	150	200	Mean
0	61.30	64.34	66.01	63.88
4	68.03	72.22	71.15	70.46
7	72.98	80.28	74.96	76.07
Mean	67.43	72.28	70.70	70.13
SOURCE		S.E.M.		C.D. (P=0.05)
Speed		0.2868		0.8096
Screen slope		0.2868		0.8096
Speed and screen slope		0.4968		1.4049

The speed and slope is observed as most effective parameter, which influence the cleaning efficiency.

The following multiple regression equations of the second order were developed by taking cleaning efficiency as a function of speeds and slopes.

Cleaning efficiency of cumin cleaner cum grader Z f (speeds, S and slopes, SS)

$$Y = 58.87 + 3.27x10^{-2}(S) + 1.74(SS)$$

(R^2 = 1; Significant at 5 % level)

Effect of feed rates, speeds and screen slopes on power consumption :

The results of power consumption of cumin cleaner cum grader at various feed rates, speeds and slopes are given in Table 4 and 5 and shown graphically in Fig. 8, 9 and 10. The mean values of power consumption at 25, 50, 75 and 100 kg/h feed rates were 0.035, 0.017, 0.012 and 0.009 Kwh/kg, respectively. From the Fig. 8, it is clear that as the feed rate increased, the power consumption decreased. The maximum power consumption was 0.035 Kwh/kg at 25 kg/h feed rate, whereas the minimum power consumption 0.009 Kwh/kg was found at 100 kg/h feed rate. The power consumption at low feed rate was more because, the cumin seed taken more time to pass through the machine at lower feed rate as compared to higher feed rate. The following multiple regression equations of the second order were developed by taking cleaning efficiency as a function of speeds and slopes.

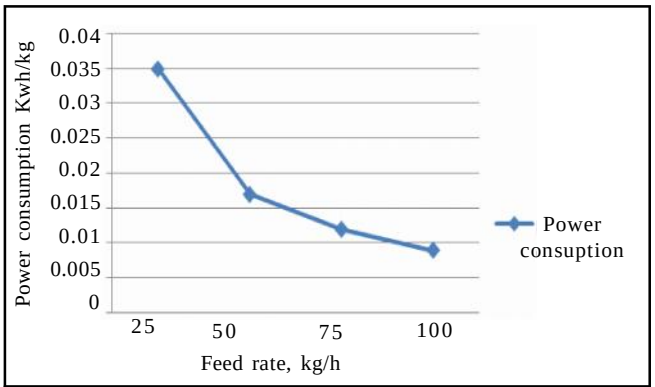

Fig. 8 : Effect of feed rate on power consumption

The mean values of power consumption for the sample at different speeds are presented in Table 4 and

Table 4: Effect of feed rate and speed on power consumption

Speed, rpm	Power consumption at various feed rate, Kwh/kg				
	25	50	75	100	Mean
100	0.037	0.018	0.012	0.010	0.019
150	0.035	0.017	0.011	0.009	0.018
200	0.035	0.017	0.012	0.009	0.018
Mean	0.035	0.017	0.012	0.009	0.018
Source			S.E.M.		C.D. (P=0.05)
Feed rate			2.745E-04		7.750E-04
Speed			2.378E-04		6.712E-04
Feed rate and speed			4.756E-04		NS

NS= Non- significant

Table 5 : Effect of feed rate and slope on power consumption

Slope, degree	Power consumption at various feed rate, Kwh/kg				
	25	50	75	100	Mean
0	0.039	0.019	0.012	0.010	0.020
4	0.035	0.017	0.012	0.009	0.018
7	0.033	0.016	0.011	0.008	0.017
Mean	0.035	0.017	0.011	0.009	0.018
Source		S.E.M.		C.D. (P=0.05)	
Feed rate		2.745E-04		7.750E-04	
Slope		2.378E-04		6.712E-04	
Feed rate and slope		4.756E-04		0.001E-04	

shown graphically in Fig. 9. The mean values of power consumption at 100, 150 and 200 rpm speeds were 0.019, 0.018 and 0.018 Kwh/kg, respectively. It is clear that as the speed increased from 100 to 200 rpm, the power consumption decreased. The maximum power consumption was 0.37 Kwh / kg at 100 rpm whereas it was minimum 0.009 Kwh/kg at 200 rpm. The lower power consumption at higher speed may be due to the reason that all the cumin seeds are not getting sufficient time on the screen and also cumin seeds may be overflowing over the screens and not passing through the holes of the screen. At lower speed the contact area per seed for cleaning will be more as compared to higher speed. The individual effect of feed rate and speed was found to be significant at 5 per cent level of significant but their interaction was found to be non-significant at 5 per cent level of significant.

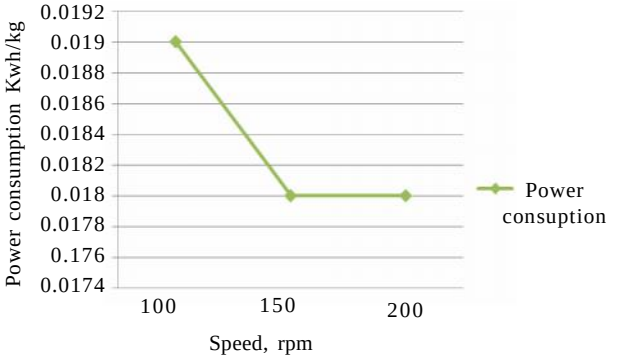

Fig. 9 : Effect of speed on power consumption

Cleaning efficiency of cumin cleaner cum grader Z f (speeds, S and slopes, SS)

$$Y = 58.87 + 3.27x10^{-2}(S) + 1.74(SS)$$

(R^2 = 1; Significant at 5 % level)

The mean values of power consumption for the sample at different slopes are presented in Table 5 and shown graphically in Fig. 10. The mean values of power consumption at 0, 4 and 7 slopes were 0.020, 0.018 and 0.017 Kwh/kg, respectively. It is clear that as the slopes increased, the power consumption decreased. The maximum power consumption was 0.039 Kwh/kg at 0 degree slope, whereas the minimum power consumption 0.008 Kwh/kg was found at 7 degree slope. The power consumption at higher slope may be due to the reason that, at higher slope, cumin seeds slides easily over the screen and passes through the holes which ultimate results in lower power consumption. The higher power consumption at minimum slope may be results of over flow of the materials over the screen and not passing through the screen. The individual effect of feed rate and slope was found to be significant and their interaction was also found to be significant at 5 per cent level of significant.

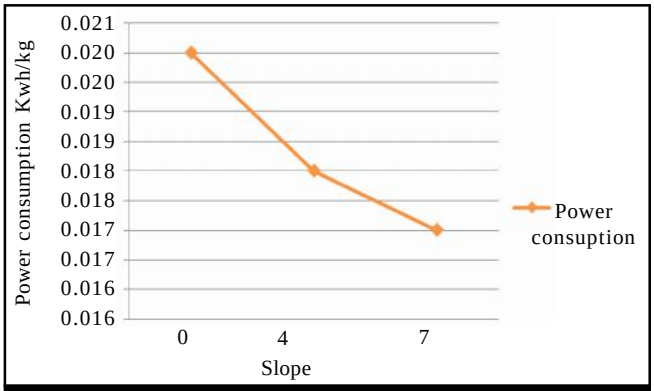

Fig. 10 : Effect of slope on power consumption

Power consumption of cleaner cum grader Z (Feed rate F, speed S and slope SS)

$$Y = 4.235x10^{-2} - 3.37x10^{-2}(FR) - 7.92x10^{-2}(S) - 4.17x10^{-2}(SS)$$

(R^2 = 0.820; Non - significant)

Cost of operation of cumin seed :

The cost of operation of the developed cumin cleaner cum grader was calculated by considering the full utilization of the machine for custom hire basis for entire season, no running capital investment has been proposed. Including the cost of machine as capital investment, the fixed cost per hour for the operation of the cleaner cum grader is the sum of depreciation, interest, etc. become Rs. 4.46/-, while the total variable cost including repair and maintenance, labour charges, electricity, etc was Rs. 10.91/-. The total cost for operating the machine for one hour was Rs. 15.37/-. Cost of cleaning of developed cumin cleaner cum grader per kg came to about Rs. 0.31/-. The developed cumin cleaner cum grader cost was Rs. 13,000/-.

Conclusion :

The medium capacity cumin cleaner cum grader

was designed and developed as described earlier was found to be suitable for cleaning and grading of cumin seeds. The developed machine classified the seeds into two grades namely, cleaned seeds and partially cleaned seeds. For obtaining the higher efficiency, the developed cumin cleaner cum grader should be operated at lower feed rate, higher slope and medium speed. Based on the results of cleaning efficiency of the developed cumin cleaner cum grader, it may be recommended that a 50 kg/h feed rate, 150 rpm and 7-degree slope is the optimum condition for cleaning in the developed cumin cleaner cum grader. The cost of the cleaning was Rs. 0.31/- per kg.

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