Optimization of Roller Speed and Feed Rate of Mini Dhal Mill for Hulling Efficiency of Pigeon Pea

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ABSTRACT

Pigeon pea is mostly consumed in the form of splits, and it provides a good source of proteins. An abrasive carborundum roller cylindrical mill was generally used in small scale to dehusk and splits pulse grains to make dhal. The independent milling parameters of laboratory scale dhal mill were roller speed and feed rate. The oil treatments to the pigeon pea grains were given after pitting. The milling parameters were (i) roller speed (1000, 1200 and 1400 rpm) (ii) feed rate (50, 60, 70 and 80 kg/h). Two factor completely randomized design was used to optimize the hulling efficiency. Roller speed and feed rate showed significantly effect on the hulling efficiency. The maximum hulling efficiency of 73.53% was found with 1400 rpm roller speed and 60 kg/h feed rate. Dhal recovery was 63.18%.

1. INTRODUCTION

Pigeon pea is mainly consumed as dhal because it takes less time to cook and has acceptable appearance, texture, palatability, digestibility, and overall nutritional quality. The recovery of dhal varies from 60 to 75%, depending upon the type of pulses and techniques adopted by the millers such as methods of pre-treatment and milling machinery used. Pulse mill (dhal mill) is an important machine for processing pulses like pea, gram, and lentil after they are harvested. Pulse mill dehusk and split grains and make them suitable for consumption. Semi automatic mini pulse mill is other type of pulse mill for dehusking and splitting pulses. There has always been a need for low-cost small-scale mill which could be owned and operated by less-skilled people in rural and semi-urban areas. Therefore, a concentric cylinder abrasive roller mill has been developed for dehusking and splitting of pulses; it has a constant clearance between outer and inner roller to give even abrasion. Considering these an attempt was made to describe the mill and its performance evaluation by systematic study of machine parameters, leading to increase the dhal recovery and reduce losses.

2. MATERIALS AND METHODS

The BDN 2 variety of pigeon pea was selected for the present investigation. The grains were cleaned manually to remove all foreign materials such as dust, dirt, stones, chaff, immature and broken grains. The clean grains were then graded by manually operated size grader to obtain uniform sized grain.

The laboratory scale dehusking machine was fabricated which mainly consisted of emery coated roller mounted on a shaft. The diameter of emery roller was 190 mm, which included the coating of emery (22 grades, as adopted by the pulse millers). A slotted screen was mounted around the emery roller cylinder. The inner diameter of slotted screen was 210 mm. The screen was made in two equal halves to facilitate frequent cleaning. These two halves were held in position through clamps and latches. There was a provision for adjusting the clearance between the screen and the emery roller either at top or bottom sides. The clearance of 10 mm between emery roller and slotted screen was fixed for present study based on its minimum requirement. The inclination was provided by keeping the inlet side about 25 mm higher than the outlet side for smooth flow of grains from inlet to outlet. The shape and volume of the hopper were trapezium and 2767.5 cm^3 respectively. The inlet feed control mechanism was provided to control the flow rate of grains in the machine. The outlet control mechanism was also provided to the finished product outlet in order to control the retention time of grains in the machine. The powder collecting trough was made up of ordinary transparent polyethylene sheet available in the market and was fixed with frame by use of velcro. The velcro arrangement facilitated easy fixing and removal of polyethylene trough (powder collecting trough) required for removing the slotted screen for cleaning purpose. The single phase electric motor of 1.0 hp was provided for the operation of dehusking machine.

The minimum size of sample, i.e., the quantity of pigeon pea grains required to conduct the milling tests was worked out on the basis of dehusking machine dimensions. Based on this, a sample size of 2 kg was selected for milling the grains. Considering the bulk density of pigeon pea grains, hopper volume was found to be 2767.5 cm^3. The square cross section outlet of hopper was having 50 x 50 mm size with a provision to adjust the hopper opening through a sliding gate.

The dehusking machine was run at different speeds to standardize the rpm of roller for deciding the final dehusking test parameters for the 2 kg sample size. The results are given in Appendix B. On the basis of the results given in Appendix B, the roller speed as 1000, 1200, 1400 rpm was selected for the dehusking tests undertaken during the study.

The oil treatments to the pigeon pea grains were given after pitting (after passing once through dehusking machine). The mustard oil applied @ 0.5 kg oil per 100 kg pigeon pea grains. After 36 h of oil treatment, the pigeon pea grains were conditioned for five days and then fed to the dehusking machine for determining the per cent husk removed to know the ultimate effect of oil treatment. All the samples of pigeon pea grains after oil treatments were dried to 10% m.c. using the laboratory scale hot air dryer at 60°C temperature. The dried and cooled pigeon pea grains were subsequently fed to the dehusking machine operated at 1000, 1200, 1400 rpm roller speed for 50, 60, 70 and 80 kg/h feed rate. The output of the dehusking machine, i.e., dehusked grains, husk and powder were collected and separated for the analysis of husk removal and hulling efficiency.

Oil treated samples of size 2 kg having about 10 ±0.5% moisture content (d.b.) were milled using laboratory dhal mill. Samples were milled at the 3 levels of roller speed (1000, 1200, 1400 rpm) and 4 levels of feed rate (50, 60, 70 and 80 kg/h) with 3 replications in completely randomized design. After milling, all the fractions were collected in polyethylene bag. Each of the samples were milled separately, care was taken to obtain all the fractions without loss using cleaning brush.

3. RESULTS AND DISCUSSION

Average percentage yield of different dehulling fractions

The average percentage yield of different dehulling fractions of pigeon pea dehulling with different roller speed and feed rate are presented in Table 1. It is clear that the average values of dehulling fractions *viz.,* dhal, unhulled grains, husk, brokens and powder were observed to be 37.58-63.18%, 14.30-46.63%, 9.09-12.13%, 2.61-5.32% and 3.02-6.38%, respectively.

Table 1 indicates that maximum dhal fraction of 63.18% was recovered with 1400 rpm roller speed and 60 kg/h feed rate (R_3F_2), whereas minimum dhal fraction of 37.58% was obtained with 1000 rpm roller speed and 80 kg/h feed rate (R_1F_4).

The 1400 rpm roller speed and feed rate of 60 kg/h (R_3F_2) recorded minimum unhulled grains (14.30%), while 1000 rpm roller speed and 80 kg/h feed rate (R_1F_4) gave maximum unhulled grains (46.63%).

The maximum husk fraction of 12.13% was obtained with 1400 rpm roller speed and 50 kg/h feed rate (R_3F_1), whereas minimum husk fraction of 9.09% was observed with 1000 rpm roller speed and 80 kg/h feed rate (R_1F_4).

The 1000 rpm roller speed and feed rate of 50 kg/h (R_1F_1) registered minimum brokens (2.61%), while 1200 rpm roller speed and 50 kg/h feed rate (R_2F_1) gave maximum brokens (5.32%).

The minimum powder fraction of 3.02% was produced with 1000 rpm roller speed and 50 kg/h feed rate (R_1F_1), whereas maximum powder fraction of 6.38% was noted with 1400 rpm roller speed and 60 kg/h feed rate (R_3F_2).

Average husk removed, coefficient of hulling, coefficient of wholeness of kernel and hulling efficiency

Average husk removed, coefficient of hulling, coefficient of wholeness of kernel and hulling efficiency of pigeon pea dehulling with different roller speed and feed rate are presented in Table 2.

It is clear that the average values of dehulling fractions *viz.,* husk removed, coefficient of hulling, coefficient of wholeness of kernel and hulling efficiency were observed to be 66.88-89.08%, 0.54-0.86, 0.80-0.88 and 45.49-73.53%, respectively.

The maximum husk removed of 89.08% was recovered with 1400 rpm roller speed and 50 kg/h feed rate (R_3F_1), whereas minimum husk removed of 66.88% was obtained with 1000 rpm roller speed and 80 kg/h feed rate (R_1F_4).

The maximum coefficient of hulling of 0.86 was obtained with 1400 rpm roller speed and 60 kg/h feed rate (R_3F_2), whereas minimum coefficient of hulling 0.54 was observed with 1000 rpm roller speed and 80 kg/h feed rate (R_1F_4).

The 1200 rpm roller speed and feed rate of 50 kg/h (R_2F_1) observed minimum coefficient of wholeness of kernel (0.80), while 1000 rpm roller speed and 50 kg/h feed rate (R_1F_1) gave maximum coefficient of wholeness of kernel (0.88).

The maximum hulling efficiency of 73.53% was observed with 1400 rpm roller speed and 60 kg/h feed rate (R_3F_2), whereas minimum hulling efficiency of 45.49% was observed with 1000 rpm roller speed and 80 kg/h feed rate (R_1F_4). At lower speed insufficient abrasion took place which resulted in slighting lower hulling efficiency. These results for hulling efficiency are in conformity with the results reported by Sahay and Bisht (1988).

Effect of different roller speed and feed rate on husk removed, coefficient of hulling, coefficient of wholeness of kernel and hulling efficiency of pigeon pea

A perusal of data presented in Table 3 reveal that different roller speed significantly influenced the husk removed. The husk removed was increased with increase in roller speed. The maximum husk removed (86.63%) was recorded with 1400 rpm roller speed, while the minimum husk removed (74.08%) was observed with 1000 rpm roller speed. Data on husk removed were significantly influenced by varying feed rate. It is clear from the table that the husk removed increased with feed rate up to 60 kg/h and reduced thereafter. The feed rate of 60 kg/h gave significantly the highest husk removed (85.49%), which remained statistically at par with feed rate of 50 kg/h. On the other hand, 80 kg/h feed rate registered significantly the lowest husk removed (75.14%), however it was statistically equivalent to 70 kg/h feed rate.

The coefficient of hulling increased with each increase in roller speed. Significantly the highest coefficient of hulling (0.833) was noted with 1400 rpm roller speed, while the lowest value was registered with 1000 rpm roller speed. A glance at Table 3 reveals that different feed rates cause their significant influence on coefficient of hulling. Significantly the highest coefficient of hulling

(0.720) was recorded with feed rate of 60 kg/h and the lowest one (0.674) was observed with 80 kg/h feed rate.

Significantly the lowest coefficient of wholeness of kernel (0.822) was recorded with 1200 rpm roller speed, while the maximum coefficient of wholeness of kernel (0.863) was noted with 1000 rpm roller speed. Data on coefficient of wholeness of kernel were significantly influenced by varying feed rate (Table 3). The feed rate of 80 kg/h gave significantly the lowest coefficient of wholeness of kernel (0.841), but it remained statistically at par with feed rate of 50 kg/h. On the contrary, 70 kg/h feed rate registered significantly the highest coefficient of wholeness of kernel (0.854), however it maintained statistical equilibrium with 60 kg/h feed rate.

The hulling efficiency increased with each increment in rpm. Significantly the highest hulling efficiency (71.45%) was recorded with 1400 rpm roller speed, while the lowest hulling efficiency (48.70%) was registered with 1000 rpm roller speed. Similar results for roller speed on hulling efficiency were also reported by Phirke *et al*. (1996) and Kumar *et al*. (2004). A perusal of data presented in Table 3 indicates that different feed rate did cause their significant impact on hulling efficiency. Similar results for hulling efficiency were also reported by Mangraj and Singh (2011).

4. CONCLUSION

1. The maximum dhal fraction of 63.18% was recovered with 1400 rpm roller speed and 60 kg/h feed rate, whereas minimum dhal fraction of 37.58% was obtained with 1000 rpm roller speed and 80 kg/h feed rate.
2. The 1400 rpm roller speed and feed rate of 60 kg/h recorded minimum unhulled grains (14.30%), while 1000 rpm roller speed and 80 kg/h feed rate gave maximum unhulled grains (46.63%).
3. The maximum husk fraction of 12.13% was obtained with 1400 rpm roller speed and 50 kg/h feed rate, whereas minimum husk fraction of 9.09% was observed with 1000 rpm roller speed and 80 kg/h feed rate.
4. The 1000 rpm roller speed and feed rate of 50 kg/h registered minimum brokens (2.61%), while 1200 rpm roller speed and 50 kg/h feed rate gave maximum brokens (5.32%).
5. The minimum powder fraction of 3.02% was produced with 1000 rpm roller speed and 50 kg/h feed rate, whereas maximum powder fraction of 6.38% was noted with 1400 rpm roller speed and 60 kg/h feed rate.
6. The maximum husk removed of 89.08% was recovered with 1400 rpm roller speed and 50 kg/h feed rate, whereas minimum husk removed of 66.88% was obtained with 1000 rpm roller speed and 80 kg/h feed rate.

7. The maximum hulling efficiency of 73.53% was observed with 1400 rpm roller speed and 60 kg/h feed rate, whereas minimum hulling efficiency of 45.49% was observed with 1000 rpm roller speed and 80 kg/h feed rate.
8. The roller speed did cause significant variation in hulling efficiency, whereas feed rate did cause their significant impact on hulling efficiency.

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Table 1: Average percentage yield of different fractions of pigeon pea dehulling with different rpm and feed rate.

Treatment	Dhal (%)	Unhulled Grains (%)	Husk (%)	Brokens (%)	Powder (%)
R_1F_1	39.93	44.96	9.48	2.61	3.02
R_1F_2	40.91	40.77	11.68	3.35	3.29
R_1F_3	40.81	42.91	10.05	2.81	3.41
R_1F_4	37.58	46.63	9.09	2.95	3.75
R_2F_1	45.79	30.98	11.78	5.32	6.13
R_2F_2	49.79	29.59	11.28	3.56	5.77
R_2F_3	48.01	30.81	11.04	3.76	6.38
R_2F_4	45.92	33.87	10.03	3.95	6.23
R_3F_1	59.90	17.57	12.13	4.83	5.57
R_3F_2	63.18	14.30	11.97	4.16	6.38
R_3F_3	61.35	17.75	11.53	3.28	6.09
R_3F_4	60.36	18.13	11.61	4.39	5.74

Table 2: Average husk removed, coefficient of hulling, coefficient of wholeness of kernel and hulling efficiency of pigeon pea dehulling with different feed rate and roller speed.

Treatment	Husk Removed (%)	Coefficient of hulling	Coefficient of wholeness of kernel	Hulling efficiency (%)
R_1F_1	69.71	0.553	0.876	48.44
R_1F_2	85.79	0.595	0.860	51.16
R_1F_3	73.94	0.573	0.868	49.70
R_1F_4	66.88	0.536	0.849	45.49
R_2F_1	86.18	0.693	0.800	55.47
R_2F_2	82.83	0.706	0.842	59.46
R_2F_3	80.98	0.694	0.826	57.31
R_2F_4	73.80	0.663	0.819	54.25
R_3F_1	89.08	0.825	0.852	70.33
R_3F_2	87.86	0.858	0.857	73.53
R_3F_3	84.83	0.823	0.867	71.42
R_3F_4	84.73	0.823	0.856	70.50

Table 3: Effect of different rpm and feed rate on husk removed, coefficient of hulling, coefficient of wholeness of kernel and hulling efficiency of pigeon pea.

Treatment	Husk Removed (%)	Coefficient of hulling	Coefficient of wholeness of kernel	Hulling efficiency(%)
Roller speed (rpm)				
1000	74.08	0.564	0.863	48.70
1200	80.95	0.689	0.822	56.62
1400	86.63	0.833	0.858	71.45
S.Em.±	1.29	0.003	0.002	0.26
C.D. at 5%	3.76	0.009	0.005	0.76
Feed rate (kg/h)				
50	81.66	0.690	0.843	58.08
60	85.49	0.720	0.853	61.38
70	79.92	0.697	0.854	59.48
80	75.14	0.674	0.841	56.75
S.Em.±	1.49	0.004	0.002	0.30
C.D. at 5%	4.34	0.010	0.005	0.88
RxF				
S.Em.±	2.58	0.006	0.003	0.52
C.D. at 5%	7.52	0.018	0.009	NS
C.V.%	5.54	1.517	0.656	1.53