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Adaptability of PKV mini dal mill for processing pulses

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Abstract
The PKV mini dal mill is commercialized and being used successfully by more than 250 users in India and one abroad. The unit is mainly meant for preparation of pulse splits (dal) from pigeonpea, black gram, green gram, soybean, etc. However, to enhance its versatility, the efforts were being made towards its probable utility for cleaning of rain affected green gram. The rain affected and powdery grains of green gram could be efficiently cleaned and polished using leather roller operated at 900 rpm with feed rate of 300 kg/h. Thus cleaned green gram could fetch 8.3% higher market price, over uncleaned one.

Keywords: Green gram, dal mill, cleaning, rain affected, cleaning efficiency

Introduction

Pulses are the chief and cheap source of body-building proteins, particularly for vegetarians and for poor because animal proteins are beyond their reach. The increase in population and stagnation of the pulse production in India has resulted in the reduction of its per capita availability from 27.5 kg in 1959 to merely 14.94 kg in 2003-2004 as compared recommended annual requirement of 23.5 kg for balanced diet (Phirke, 1993) [1]. India produced 15.24 million tons of pulses during 2003-2004 (Anon., 2005).

Akola centre has developed the technologies like PKV mini dal mill, which have a potential for its adoption at small scale. In order to provide rural employment and upliftment of economic condition of villagers, the PKV mini dal mill is commercialized and being used successfully by more than 250 users in India and one abroad. The unit is mainly meant for preparation of pulse splits (dal) from pigeonpea, black gram, green gram, soybean, etc. The capacity of this dal mill is 8-10 q for pigeonpea and 10-12 q for green and black gram per day (8h). The respective recoveries are 72-75% and 82-85%. However, The PKV mini dal mill had been tested for its versatility for wheat cleaning and blackened jowar polishing, and found highly suitable for the same.

For further enhancement of versatility of PKV mini dal mill, the cleaning of rain affected green gram was thought to be performed in order to fetch higher market prices by imparting luster and removing rain affected grains.

In view of the aforesaid discussion, the present work was undertaken with the objective to enhance versatility of PKV mini dal mill for cleaning rain affected green gram.

Materials and methods

PKV mini dal mill

With view that producer should become processor the "PKV Mini dal Mill" is developed . It comprises of two machines, cleaner-grader-polisher and PKV Mini dal mill running on one and two horse power single phase electric motors, respectively. Almost all pulses can be dehulled with these machines and the products are quite comparable with that of the commercial dal mill. With a demandful product and low investment, this enterprise is certainly techno-economically feasible. This plant is commercially manufactured and available in the market. The plant requires low investment and about 200 m^2 area for operation with proper storage facility. The capacity is 8-10 q pigeonpea and 10-12 q green and black gram per day (8h). The respective recoveries are 72-75% and 82-85%. The other pulses such as soybean, cowpea, etc. can also be processed with easy operation.

It avoids dusty atmosphere and provides easy operation. The technology offers rural employment through tiny enterprise. The versatility has been enhanced for wheat cleaning and blackened sorghum polishing.

Fixed machine parameters

The experiment was conducted to assess the performance of PKV mini dal mill for cleaning of green gram using following parameters of the machine (sieve unit), which were kept constant.

Sieve Unit

Screen surface area, m^2 - 0.1856 (0.58 m x 0.32 m)
(Both upper and lower screen)
Screen perforation, mm
Upper screen - 2.73 mm
Lower Screen - 2.5 x 20 mm
Stroke length, mm - 18
Operational speed, rpm - 397
Air velocity, m/s - 1.16
Angle of sieve, degree - 7.77

Variable machine parameters

The following machine parameters were varied in order to verify their effects on cleaning of green gram.

1. Type of roller (3 levels)

R1 - Rubber roller
R2 - Leather roller
R3 - Nylon brush roller

2. Roller speed, rpm (2 levels)

S1 - 900 (9.42 m/s at inlet and 11.77 m/s at outlet)
S2 - 1200 (12.56 m/s at inlet and 15.70m/s at outlet)

3. Feed rate, kg/h (3 levels)

F1 - 200
F2 - 300
F3 - 400
No. of experiments - 18
Replications - 2
Design -Factorial CRD

The process variables considered for experimentation were type of roller, speed of roller and feed rate. The responses were taken as were studied for optimum cleaning of mung.

Operation of the machine

The sieve unit of PKV mini dal mill was modified by providing 2.73 mm dia aperture upper sieve (scalper) and 2.5 x 20 mm aperture lower sieve (grader). Rollers were fabricated by using rubber, leather and nylon brush. For changing speed, the existing pulley (127 mm diameter) at the end of the roller shaft providing 900 rpm was replaced by 90 mm diameter pulley for providing 1200 rpm. Various feeler trials (6 trials for each feed rate) were undertaken for maintaining constant feed rates. This was done by feeding 10 kg of mung grains in the hopper and inlet and outlet was kept closed, then the inlet was opened and about 4 kg grains were allowed to pass in the gap between the roller and the sieve (untill its full capacity). Then the outlet was opened to such a level so as to maintain the flow rate of 200 kg/h. After six trials (replications) the feedrate was confirmed and the markings were marked on inlet and outlet controlling mechanism for maintaining constant feed rate of 200 kg /h. The same procedure was adopted for deciding the other feed rates such as 300 kg /h and 400 kg/h. The variety of mung grain used was Kopargaon small. The sample size was 10 kg for each replication.

Experimental Methodology

Before starting the test, the physical properties of grain such as moisture content, hardness, angle of repose, weight of 1000 grain and bulk density were measured. After the test was over, various observations such as impurities present in feed and clean grain, per cent clean seed present in outflow of blower, roller outlet, overflow of first screen and underflow and brokens present in feed, clean grain, and under flow were recorded. The cleaning efficiency was calculated as suggested by Bureau of Indian Standard (BIS) is given below. (IS 5817: 1980).

$$\text{Cleaning efficiency} = \frac{E\,(F-G)\,(E-F)\,(1-G)}{F\,(E\text{-}G)^2\,(1-F)}$$

Where,
E = Fraction of clean seed at clean seed outlet
F = Fraction of clean seed in feed
G = Fraction of clean seed at foreign matter outlets

The brokens before cleaning and after cleaning (in clean grain and underflow outlet) were also measured.
The visual colours were recorded by panel of five trained judges and consumer appeal with respect to market value was also assessed to optimize process parameters.

Experimental work

The variety of mung grain used for cleaning was Kopergaon small. The physical properties of the mung grain used for cleaning are shown in Table 2. The 1000 grain mass was 44.69 (± 0.84 SD) g at 9-10% moisture content. The hardness of the grain was 4.83 (± 0.425 SD) kg/cm^2, the angle of repose was 13.39° (± 0.91° SD) and bulk density was observed to be 0.80 (± 004 SD) g/cm^3.
The efforts have been made to standardize type of roller, speed of roller and feed rate for better mung cleaning. The response parameters like cleaning efficiency, visual colour and per cent brokens after cleaning were as shown in Table.

Effect of various process parameters on responses

Cleaning efficiency

The cleaning efficiency was calculated using Eq 1. From Fig 5 and Table 4, it is seen that the feed rate affected the cleaning efficiency at the most, followed by type of roller and speed of roller. The interaction of type of roller and feed rate had highest impact on cleaning efficiency follwed by interaction of type of roller and speed of roller. The cleaning efficiency decreased continuously and significantly with the increase in feed rate from 200 kg/h to 400 kg/h. Thus feed rate of 200 kg/h could ensure maximum cleaning efficiency in case of all type of rollers and all roller speeds, because at lower feed rates the maximum retention of time for grains with roller and on screens facilitates proper clod breaking, trash crushing and efficient separation of impurities over screen. The cleaning efficiency was observed to be affected by type of roller also. The rubber roller could impart minimum cleaning efficiency while cleaning efficiency imparted both by leather and nylon brush rollers were at par. The rubber roller facilitates more kinetic energy to the grains thereby making them roll over the separation screen, instead of getting dropped down through the screen apertures. Therefore, in case of rubber roller, the maximum clean seed were observed in overflow outlet which leads towards decrease in cleaning efficiency. The roller speed revealed non-significant effect on cleaning efficiency.

Colour score

From Fig 6 and Table 5, it can be seen that all the variables like type of roller, speed of roller and feed rate had significant effect on colour score. However, the speed of roller affected the colour most followed by feed rate and type of roller.

The output from leather roller could be seen with maximum luster followed by rubber roller and then by nylon brush roller. It shows that leather roller was more helpful in removing the affected grain by splitting (as indicated in Table 3) and removing the powdery appearance from grain surface which may be due to individual characteristics of this roller and pressing of grains against screen cylinder wall from inside besides impact action (Fig.

The colour score for all samples at speed of 900 rpm was higher than that for corresponding samples obtained at 1200 rpm of rollers. There was possibility that due to higher speed of roller, the internal resistance caused due to grains between roller surface and inside surface of screen cylinder, the rolling speed of roller might be decreased in case of all rollers. Thus, at higher rpm of machine no sufficient cleaning reaction could be seen, besides higher splits and broken.

The feed rate was prominent in affecting colour score of cleaned samples. The lower feed rate could ensure more luster and glossy appearance to cleaned mung grains. This may be due to longer retention of grains along roller. The colour score decrease significantly with increase in feed rate, as the retention time decreased. The interaction of roller type and roller speed had highest impact on colour score.

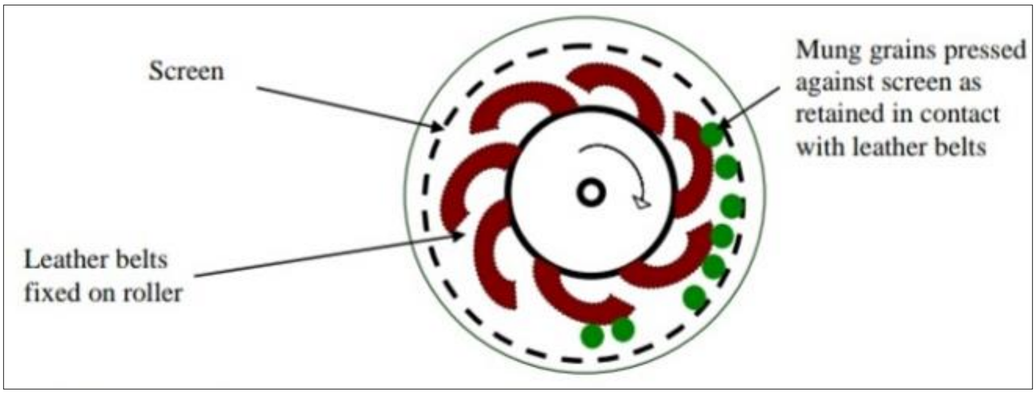

Fig 1: Pressing, rubbing and impact cation by leather belt on mung grains during operation

3. Splits and broken in undersize outlet

From Figure and Table, it can be seen that speed of roller was most prominent factor in affecting the quantity of undersize produced. At higher speeds, the internal resistance caused due to grains between roller surface and inside surface of screen cylinder lead towards formation of more split and broken in case of all rollers. In case of leather roller, the impact action led towards more percent of splits (Fig. 1 and Fig. 2) in undersize outlet as most of the rain-affected grains are getting split by impact action (as happens in case of splitter).

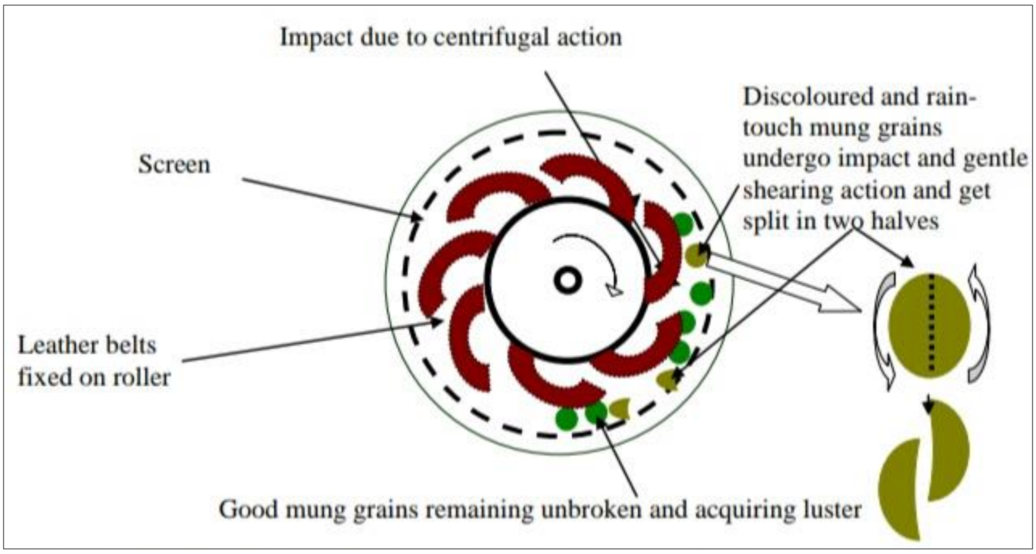

Fig 2: Pressing, (shearing) rubbing and impact action by leather belt on mung grains during operation

The % split in undersize of rubber roller was less whereas because of continued shearing action, more broken (as compared to that obtained using leather roller) was obtained (Fig. 1, Fig 2 and Fig. 3).

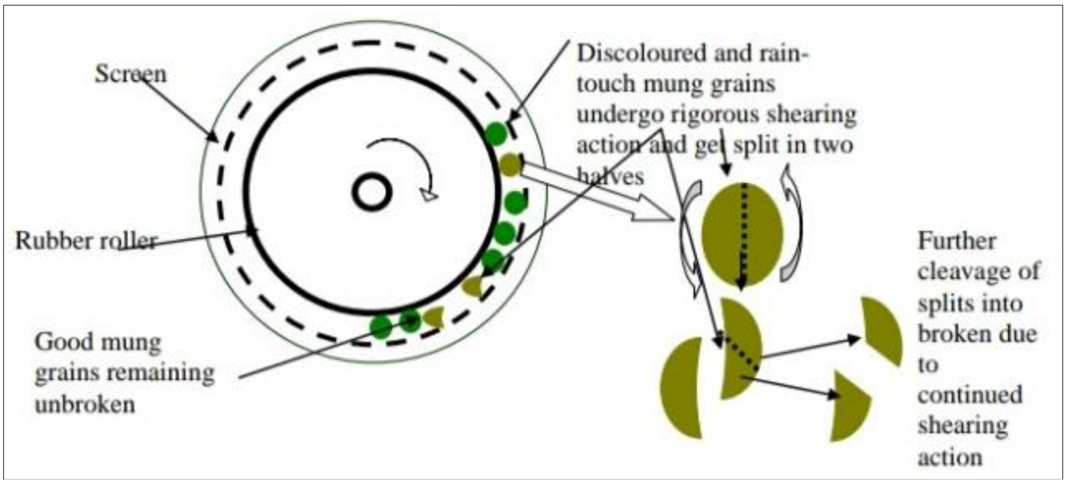

Fig 3: Shearing action by rubber roller on mung gains during operation

In case of Nylon brush rollers, the weak grains were being sheared till they were not released through brush, thereby, even with lesser percent of splits in undersize outlet, the proportion of broken was higher (Fig. 2, Fig 3 and Fig. 4).

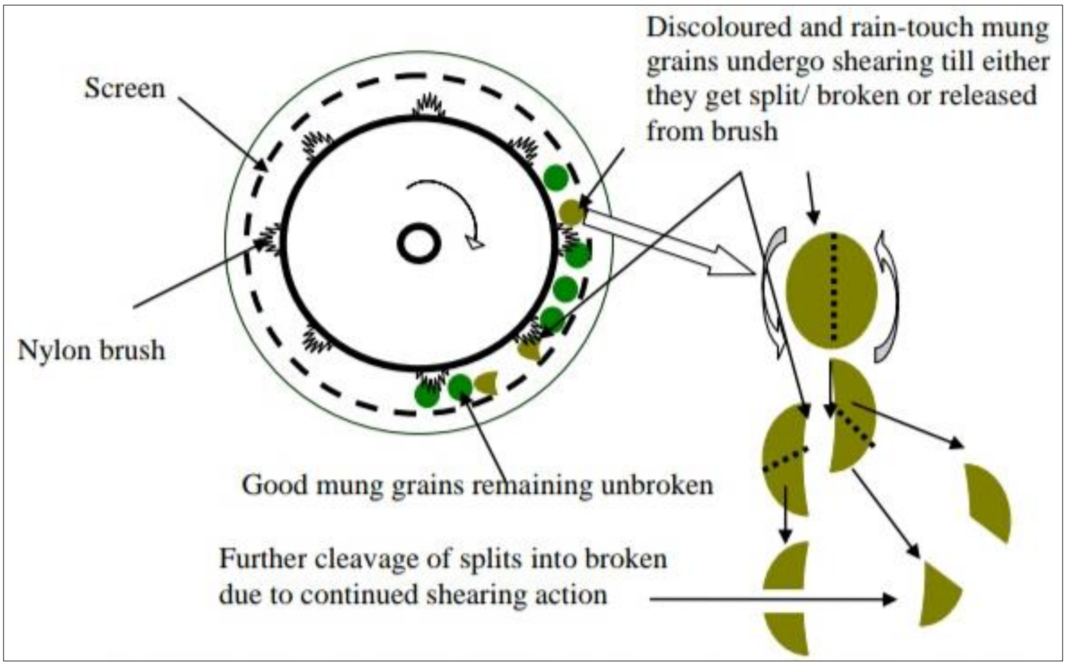

Fig 4: Shearing action by rubber roller on mung grains during operation

The feed rate was least affecting the quantity of undersize at respective outlet. But with increase in feedrate the undersize outlet output was found to be decreasing significantly (Fig. 4). This may be due to longer retention period of grains in cylinder facilitated by lower feed rates and vice versa. From visual observations of crushed samples it could be seen that 9 to 10% grains are rain affected and need to be split or broken and separated so as to improve the quality of cleaned seeds. From Table, it can be observed that at roller speed of 900 rpm, for Rubber and Nylon brush type of roller, the total splits and brokens were varied from 9.56 to 15.51% which was in close agreement with the requirement (9 to 10%). But in case of leather roller, the splits and brokens (undersize outlet) were accounted upto 15.14 to 22.18% depending on feed rate, thereby ensuring crushing of almost all rain affected and weak grains. The leather roller could reveal the advantage of more per cent of split (i.e. about 90%) in undersize outlet, ensuring better quality splits obtained in undersize port. These splits could be separated from broken by using screen with 2.5 mm diameter apertures.

The interaction (Table 6) of type of roller and speed of roller had highest influence on quantity of undersize obtained followed by interaction of roller type and feed rate and subsequently interaction of speed and feed rate.

From above discussion and Table 4, 5 and 6, this could be seen that minimum feed rate (200 kg/h) with lower roller speed of 900 rpm using leather roller could be used with optimum results w.r.t. cleaning efficiency and colour score. The undersize outlet output could be treated as subsidiary response, as it was just necessary to remove all the available affected grains (9 to 10%).

Owing to above results, the cleaned samples were prepared by using leather rollers and 900 rpm at various feed rates from 200 to 400 kg/h. The samples were tested for consumers' appeal and market value and the results were as shown in Table 7.

From the Table 7, it can be seen that though the samples obtained using feed rate of 200 kg/h had higher colour score than that of samples prepared using feed rate of 300 kg/h, as this luster was not felt as if imparted naturally led towards lower prices of this sample, than that for sample obtained at 300 kg/h of feed rate.

Thus, the feed rate of 300 kg/h was thought to give preference over 200 kg/h as to get 8.3% higher market price. This shows that about Rs. 150/- can be obtained as against cleaning of one quintal mung grains.

From above discussion, the optimized process parameters are decided as below.

A) Process variables

Type of roller - leather
Speed of roller - 900 rpm
Feed rate - 300 kg/h

B) Major Response variables

Cleaning efficiency - 98.845%
Colour score - 7.75

C) Other responses

Split and broken in undersize outlet - 20.69%
% split in undersize - 90. 90% (18% of feed quantity)
% broken in undersize - 09.10% (about 2% of feed quantity)
Market price - 8.3% more than that for un-cleaned mung

Conclusion

1. The PKV mini dal mill was found to be techno-economically feasible for commercial adoption
2. The versatility of PKV mini dal mill was enhanced for mung cleaning. The rain affected and powdery grains of mung could be efficiently cleaned and polished using leather roller operated at 900 rpm with feed rate of 300 kg/h besides fetching 8.3% higher market price.

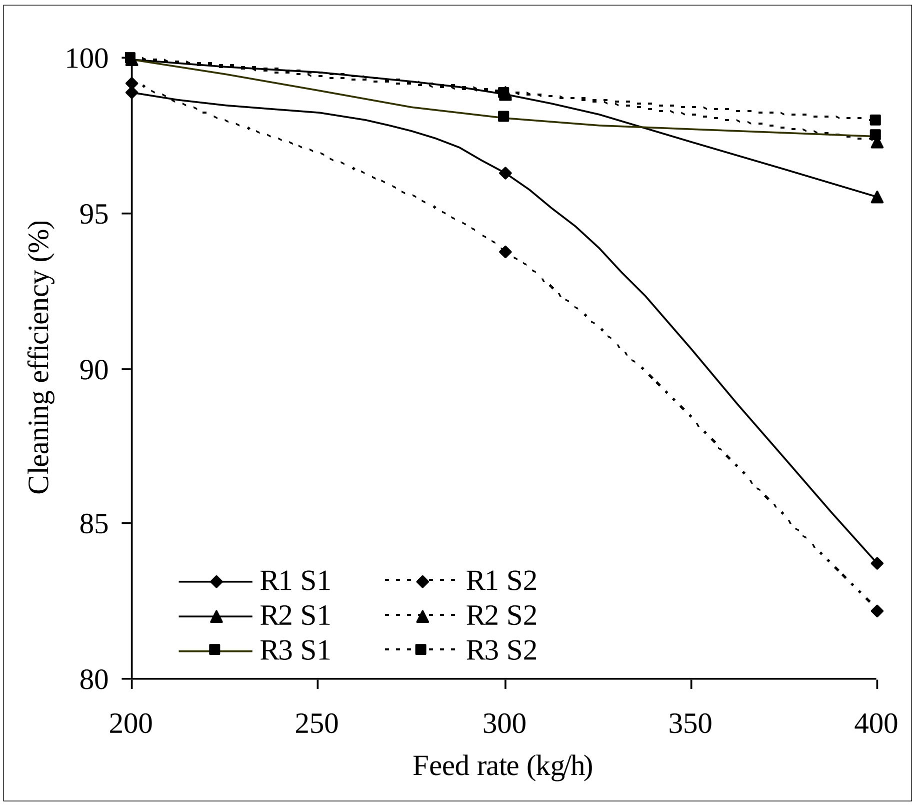

Fig 5: Effect of feed rate, type of roller and roller speed on cleaning efficiency (%)

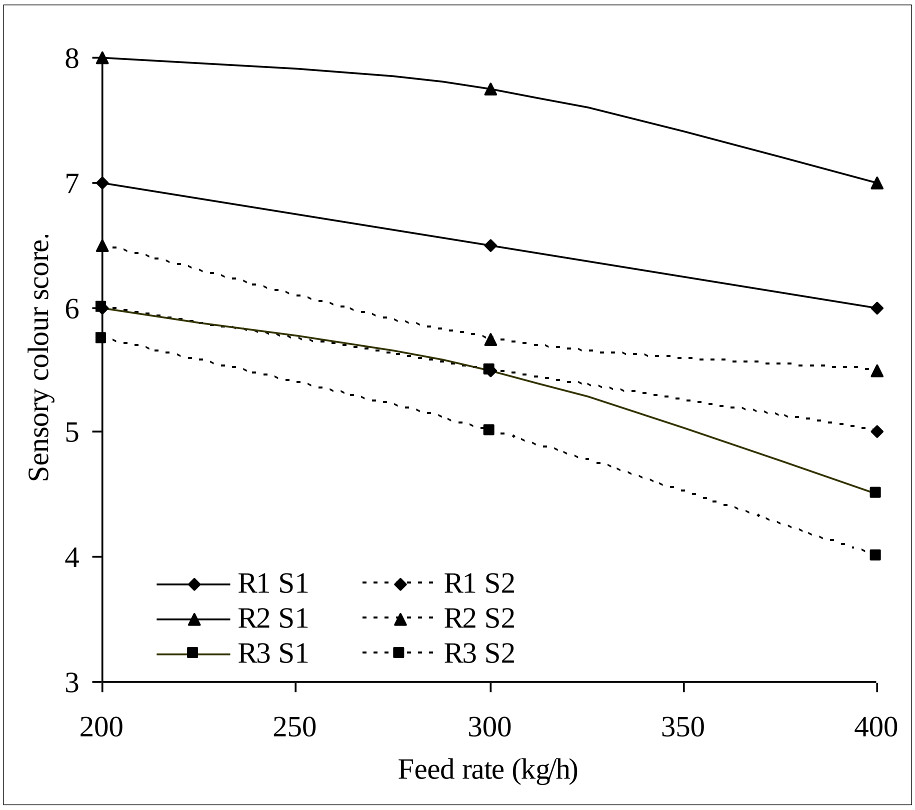

Fig 6: Effect of feed rate, type of roller and roller speed on sensory colour score

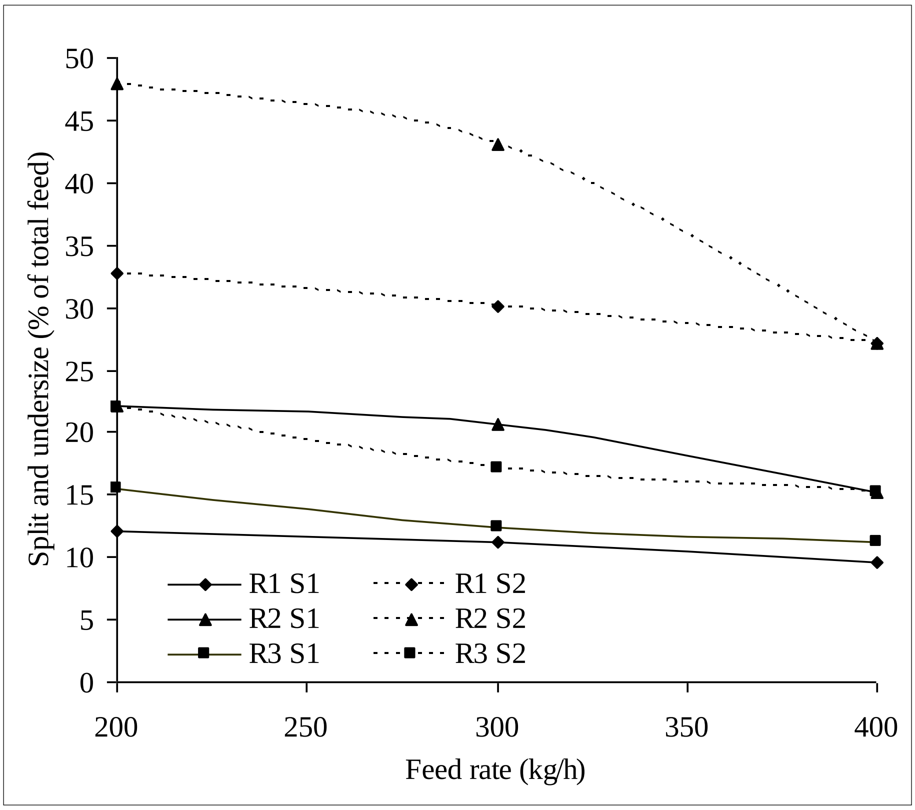

Fig 7: Effect of feed rate, type of roller and roller speed on split and undersize at undersize outlet

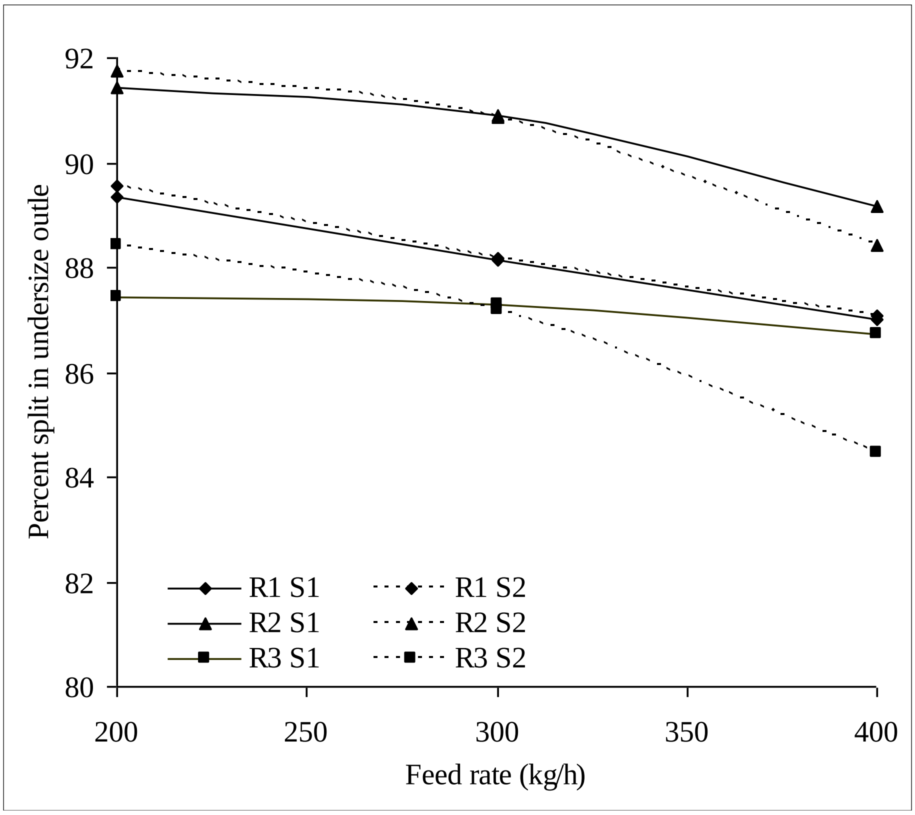

Fig 8: Effect of feed rate, type of roller and roller speed on percent split at undersize outlet

Table 1: Physical properties of mung grain used for cleaning

Moisture content (%)	9-10
1000 grain weight, g	44.7 (± 0.84)
Hardness, kg/cm^2	4.83 (± 0.425)
Angle of repose, degree	13.39 (± 0.391)
Bulk density, g/cm^3	0.80 g/cm^3 (± 0.004)

Table 2: Effect type of roller, roller speed and feed rate on various response parameters

Type of Roller	Feed rate (kg/h)	Cleaning Efficiency (%)		Colour score (Luster)		% split & broken (undersize)		% clean seed in Overflow		% broken in undersize		% split in undersize	
		S1*	S2*	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Rubber (R1)	200 (F1)	98.89	99.16	7.00	6.00	12.14	32.80	94.66	93.30	10.65	10.69	89.35	89.31
	300 (F2)	96.27	93.77	6.50	5.50	11.15	30.10	86.95	86.75	11.87	11.83	88.13	88.17
	400 (F3)	83.74	82.15	6.00	5.00	9.56	27.13	70.92	77.46	13.00	12.90	87.00	87.10
Leather (R2)	200 (F1)	99.92	99.93	8.00	6.50	22.18	47.90	77.38	88.60	8.55	8.24	91.45	91.75
	300 (F2)	98.84	98.87	7.75	5.75	20.69	43.05	73.85	86.73	9.10	9.56	90.90	90.44
	400 (F3)	95.54	97.26	7.00	5.50	15.14	27.20	71.81	82.55	10.84	11.56	89.16	88.44
Nylon brush (R3)	200 (F1)	99.92	99.92	6.00	5.75	15.51	21.95	70.50	76.70	12.72	12.79	87.28	87.21
	300 (F2)	98.04	98.84	5.50	5.00	12.36	17.15	66.50	69.50	13.28	14.12	86.72	85.88
	400 (F3)	95.49	95.01	4.50	4.00	11.22	15.15	56.50	63.60	13.58	15.55	86.42	84.45

*S1= Roller speed of 900 rpm, S2=Roller speed of 1200 rpm

Table 3: Cleaning efficiency

Factor	Means		F-value	CD(5%)	CV(%)
R*	92. 33167^{a**}	98.39667^{b}	98.6900^{b}	645.50	0.41963
S*	96.51822^{a}	96.42734^{b}	0.68	NS	
F*	99.62375^{a}	97.43853^{b}	91.5317^{c}	697.15	0.41963
Interaction					
R-S			13.14	0.59345	
R-F			273.84	0.72683	
S-F			1.92	NS	0.51

*R: Roller, S: Speed (rpm), F: Feed rate (kg/h)
* The values superscripted by similar letters are not significantly differing from each other

Table 4: Colour score (Luster)

Factor value		Means	F-	CD(5%)	CV(%)
R**	6.00000^{a*}	**6.75000^{b}**	5.125^{c}	79.375×10^{10}	0.271109x10^{-5}
S*	6.47222^{a}	5.44444^{b}		95.069×10^{10}	0.221359x10^{-5}
F*	6.54167^{a}	6.00000^{b}	5.333^{c}	93.95×10^{10}	0.271109x10^{-5}
Interaction					
R-S				11.736x10^{10}	0.383406 x10^{-5}
R-F				1.458x10^{10}	0.469574 x10^{-5}
S-F				0.486x10^{10}	0.383406 x10^{-5} 0.57

*R: Roller, S: Speed (rpm), F: Feed rate (kg/h)
*The values superscripted by similar letters are not significantly differing from each other

Table 5: Quantity of undersized (split and broken) in undersize, outlet

FACTOR	CD(5%)	MEANS	F-value	CV(%)
R*	20.48000^{a**}	29.36000^{b}	15.55667^{c}	587.251 0.963577
S*	14.43889^{a}	29.15889^{b}	1950.10	0.786757
F*	25.41333^{a}	22.41667^{b}	17.56667^{c}	188.145 0.963577
Interaction				
R-S		167.02	1.36270	
R-F		28.85	1.66896	
S-F		25.22	1.36270	5.16

* R: Roller, S: Speed (rpm), F: Feed rate (kg/h)
* The values superscripted by similar letters are not significantly differing from each other

Table 6: Comparison of samples prepared by leather roller and 900 rpm using market acceptability

S. No.	Particulars of sample	Sensory colour score of sample	Market value of samples (Rs./q)	Percent increase over market price of un-cleaned sample
1.	Feed sample	5.00	1800	-
2.	Feed rate, 200 kg/h	8.00	1925	6.9%
3.	Feed rate, 300 kg/h	7.75	1950	8.3%
4.	Feed rate, 400 kg/h	7.00	1900	5.5%
5.	Good quality sample available in market	9.00	2100	16.7%

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