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SURFACE POLISHING OF MOLD AFFECTED SORGHUM

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Abstract: The experiments were conducted on surface demolding of mold affected Sorghum at AICRP on Post Harvest Technology using PKV mini dal mill. The PKV mini dal mill was modified and used for polishing of mold affected sorghum. The polishing trials were conducted by using 5 types of rollers (Emery No. 40, Emery No. 60, Emery No. 80, nylon brush roller and leather roller), four feed rates (90, 120, 150 and 180 kg/h) and two rotating speed of roller (900 and 1200 rpm). It was found that the PKV mini dal mill with some modifications can be used to polish mold affected sorghum.
Keywords: Mold affected sorghum, polishing.

Introduction

Sorghum (*Sorghum bicolor* L) is an important cereal crop for food and fodder of Indian next to rice, wheat and maize. Largest share of country's production is contributed by Maharashtra and Karnataka states. Due to its ability to grow in dry lands of tropical Africa, India and China it has become the staple diet of these countries also (Shobha *et al*., 2008). Sorghum is the main staple food of Maharashtra, Karnataka, and is also an important food of Madhya Pradesh, Tamil Nadu and Andhra Pradesh.

Generally it seems that wet weather (untimely rains) following flowering and grain development is necessary for grain mold development (Rao and Williams, 1977), which appears black in colour and fetches very low price in the market. The longer the wet period, greater the mold development. The blackening was found to be limited only to the surface layers. The intensity of molding was variable within a lot of grains of same cultivars. This situation happens to be occurred many a times in our region which lowers the market value of sorghum grain. This mold can be removed to some extent if the grains are polished. Sorghum grains are polished with a pearling machine and processed in to flour as well as *rava* (*suji*) of different particle size (coarse *rava*, medium *rava* and fine *rava*). Protein quality and essential amino acid profile of sorghum is better than many of the cereals and millets. Sorghum in general is rich source of fiber and B-complex vitamins (Gopalan *et al*., 2000; Patil *et al*., 2010). Sorghum can be processed in to various products such as pops, starch, and

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grits (*semolina/rava*) from which many ethnic/niche food products can be made (Chavan *et al.,* 2013.).

A surface demolder/polisher can be developed for this purpose which will remove the surface mold (blackened portion) to some extent and the sorghum grain will fetch better price in the market. Polishing the jowar did not lead to any nutrition-specific changes of the protein (Manjrekar *et al.,* 1986).

Objectives

1. Modification, testing and evaluation of PKV Mini dal mill for surface polishing of mold affected sorghum
2. To study the shelf life of polished sorghum
3. Conduction of large scale trials of modified PKV Minid dal mill for surface demolding
4. Study of techno-economic feasibility

Materials and Methods

The PKV mini dal mill was tested for surface polishing of the mold affected sorghum by modifying the existing dal mill with suitable modifications such as changing roller and speeds of the machine. This machine is having all operations in one unit such as dehusking, separating husk, powder and brokens also. The machine consists of four units viz. elevator, dehulling unit, separation unit and screw conveyor (Fig. 1.1). It requires two horse power single phase electric motor for complete operation.

Dehulling unit

It consists of an abrasive horizontal conical cylinder rotating in order to achieve smooth flow of grains during dehulling. The cylinder is covered by a metal sieve with a specific clearance. The sieve facilitates the partial separation of husk and powder. The inlet and outlet are provided on side plates at the top and bottom, respectively with separate controls by hand wheel and lever.

Separation unit

The unit comprises of the three components viz. blower, sieve unit and cyclone separator. When the dehulled mixture is allowed to fall on the sieve unit, the blower separates the husk and powder from it and passes to the cyclone separator. The mixture of husk and powder falls out from bottom of the cyclone separator and air escapes from top. Thus unit avoids the dusty atmosphere.

Sieve unit

The four point suspension system is provided to sieve unit resting on main frame with reciprocating motion.

Transmission system

Prime mover supplies power directly to the dehulling unit as it consumes major part. The second belt provides power to the counter shaft, which operates all the other units of dal mill. The whole power transmission is achieved through v-belts and pulleys. The sieve unit reciprocates through connecting rod from eccentric mechanism installed on counter shafts.

The sieve unit was modified by providing sieve of 2 mm diameter aperture. The emery powder of 40, 60 and 80 no. and by using nylon brush and leather.

For changing the speed, the existing pulley (127 mm diameter) at the end of roller shaft providing 900 rpm was replaced by 90 mm diameter pulley providing 1200 rpm. The hand lever at outlet control was modified by providing screw mechanism for precision control of outlet opening. Various feeler trials (6 trials for each feed rate) were undertaken for maintaining constant feed rates for better polishing. This was done by feeding 10 kg grains in the hopper and inlet and outlet wa kept closed, then the inlet was opened and about 3 kg grains were allowed to pass in the gap between the roller and the sieve (until its full capacity). Then the outlet was opened to such a level so as to maintain the flow rate of 90 kg/h as well as better polishing. Same procedure was adopted for deciding the other feed rates such as 120 kg/h, 150 kg/h and 180 kg/h. The markings were given on inlet controlling mechanism and outlet controlling mechanism for maintaining constant feed rates of 90 kg, 120 kg/h, 150 kg/h and 180 kg/h.

The variety of grains sorghum (blackned) used for testing was CSH-9. The sample size was 10 kg for each replication. Before starting the test, the physical properties of the grains such as moisture content, hardness and weights of 1000 grains were observed. For brining moisture content to the desired level of 13.5%, known amount of water was sprinkled over the grains and kept for conditioning for about 20 minutes.

The following treatments were considered for testing PKV mini dal mill for polishing of mold affected sorghum by using PKV mini dal mill.

M.C. (w.b.) of sorghum grain : 13.5%

Rollers used for polishing

1. R1- 40 no. emery roller
2. R2- 60 no. emery roller

3. R3- 80 no. emery roller
4. R4- Nylon brush roller
5. R5- Leather roller

Speeds used for polishing

1. S1 – 900 rpm
2. S2 – 1200 rpm

Feed rates used for polishing

1. F1- 90 kg/h
2. F1- 120 kg/h
3. F1- 150 kg/h
4. F1- 180 kg/h

Replications

After the test was over the whole polished grains, broken and powder were measured for each replication. The mold rating of whole polished grains was also observed. Data was

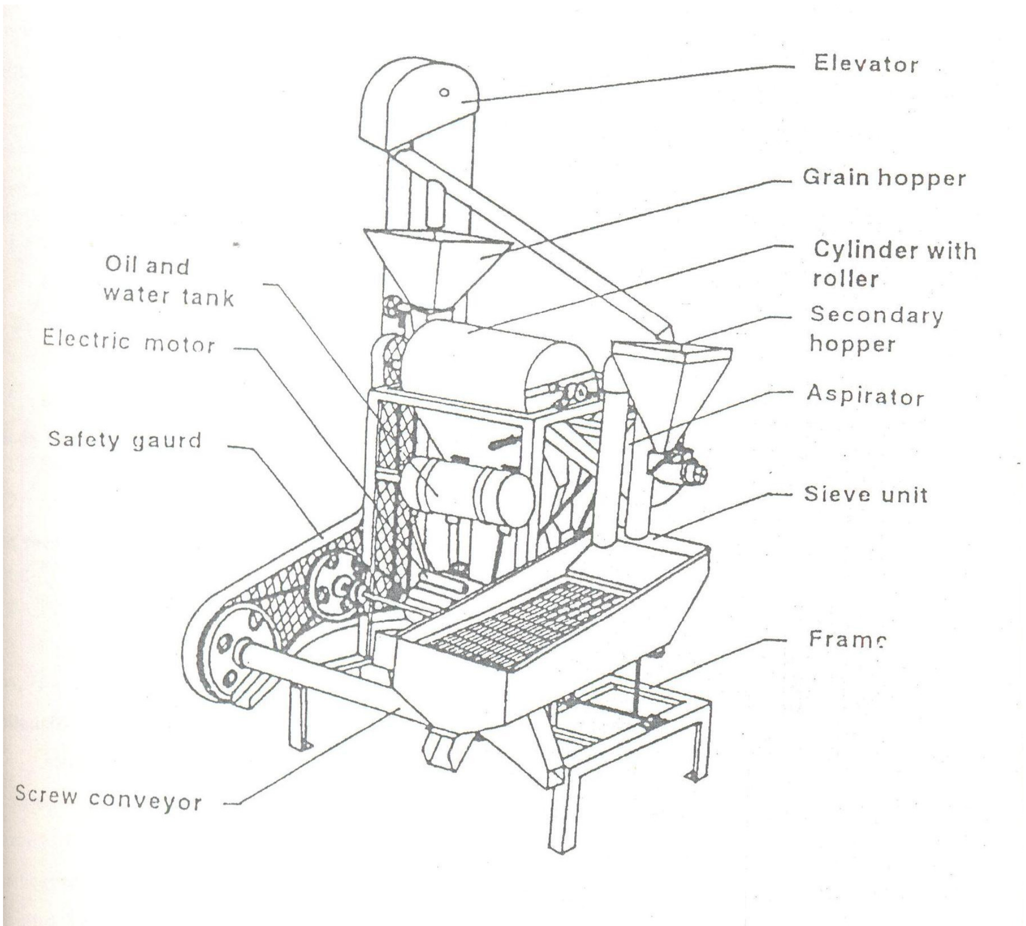

Fig 1. PKV mini dal mill (2 hp)

statistically analysed by using analysis of variance by one way classification. The per cent incidence of mycoflora, protein and carbohydrate content, temperature and RH was observed for whole polished grains and mold affected grains. The mycoflora was observed by standard blotter paper method. The protein content was determined by micro Kjehldal's method and carbohydrates were determined by Flame photometric method.

Results and Discussion

The variety of mold affected grain sorghum used for polishing was CSH-9. The physical properties of the grain sorghum are shown in Table 1.1. The mold rating scale given in Table 1.2 was used for determining the mold rating of whole grains.

The test results of polishing of mold affected sorghum by using PKV mini dal mill using various treatments are shown in Table 1.3 to 1.12.

Roller

Table 1.3 shows effect of different rollers on mold rating, whole grain, broken and husk and powder. Maximum removal of mold (3.33) was due to roller R3 (emery no. 80). It was significantly better than any other roller and was followed by roller R2 (emery no. 60) and roller R1 (emery no. 40), respectively. The R4 (nylon brush roller) and R5 (leather roller) could not remove sufficient mold (Table 5.3).

As regards the effect of roller with respect to whole grains, maximum quantity of whole grains were observed in R4 (nylon brush roller) and R5 (leather roller), which were at par. However both of these rollers can not be considered for polishing point of view, as it was observed that these rollers can not be considered for polishing of blackened sorghum grains. These were followed by roller R2 (emery no. 60) and roller R3 (emery no. 80) both being at par with each other and significantly better than roller R1 (emery no. 40).

As regards broken grains due to different rollers, minimum broken grains were observed in R4 (nylon brush roller) and R5 (leather roller) both being at par with each other. These were followed by roller R2 (emery no. 60) and R3 (emery no. 80). Significantly maximum broken grains were observed by using R1 (emery no. 40).

Similar trend was observed for husk and powder. Significantly minimum husk and powder was observed by using roller R4 (nylon brush roller) followed by R5 (leather brush roller). Significantly maximum husk and powder was observed in Roller R1 (emery no. 40). There was no significant difference existed between roller R2 (emery no. 60) and roller R3 (emery no. 80) indicating superiority of roller R3 (emery no. 80) over others as it has reduced the mold rating to sufficient extent.

Feed rate

Among the various feed rates tested for the polishing of mold affected sorghum, minimum feed rate of 90 kg/h was effective in polishing the grains thereby reducing the mold rating to sufficient extent and was significantly better than rest of all the feed rates followed by 120 kg/h, 150 kg/h and 180 kg/h (Table 1.4).

In case of whole grains significantly highest whole grains were observed at 180 kg/h and was followed by 150 kg/h, 120 kg/h and 90 kg/h. Thus, as the feed rate was reduced, the amount of whole grains obtained after polishing was also reduced. This was because of the more retention time period of grains between roller and sieve. In case of less feed rate, exposure of grains to the rollers for more time resulting in more breakage and thereby reducing the whole grains.

Significantly minimum broken grains were observed in 180 kg/h feed rate, followed by 150 kg/h, 120 kg/h and 90 kg/h. Thus as the feed rate was decreased, the brokens were increased for the same reason given before. Likewise significantly minimum husk and powder was observed at 180 kg/h than any other feed rate.

Speed

As shown in Table 1.5, speed of 1200 rpm has shown significantly less mold rating (good polishing) than in 900 rpm. This was because the grains were exposed for more number of times to the roller surface resulting in less mold rating (better polishing). As regards the whole grains, maximum grains were observed at speed of 900 rpm than1200 rpm. The brokens and husk and poweder were observed minimum at 900 rpm for the same reason given before.

Interaction of effect of roller and feed rate

As regared the effect of roller and feed rate (Table 1.6) on the mold, minimum mold rating (2.67%) i.e. better polishing ws observed by using roller R3 with feed rate 90 kg/h and 120 kg/h with no significant difference and was significantly better than any other roller and feed rate.

As regard the quantity of polished whole grains, no significant differences was observed with feed rate 150 kg/h and 180 kg/h for nylon brush roller and it was at par with leather roller for same feed rate and was significantly better than any other roller and feed rate. However by using these two rollers (R4 and R5) and these two feed rates (F3 and F4), the mold rating is not reduced to acceptable rangen (6) which indicates polishing is not good and hence this combination of rollers and feed rate is not useful.

The significantly minimum quantity of broken grains was observed at feed rate 180 kg/h and for leather roller (R5). It was at par for same feed rate with nylon brush roller (R4) and was significantly lower than any other roller and feed rate. But even though the quantity of brokens obtained by using above combination is less, the mold rating is not reduced to much extent and retains 6 month only, which indicates very less polishing and hence the combinatioin is not useful.

Significantly minimum quantity of husk and powder was observed with 90, 120, 150 and 180 kg/h for nylon brush roller and was at par with the same feed rate for leather roller and it was significantly better than any other roller. But using these combination mold rating is not redued to much extent hence these combinations can not be considered better for polishing black mold sorghum.

Interaction effect of roller and speed

The minimum mold was observed on polished whole grains at the speed of 1200 rpm and for roller with 80 no. emery and hence it was minimum and was significantly better than any other roller and feed rate (Table 1.7).

As regard the quantity of whole grains, the maximum whole grains were observed at nylon brush roller and 900 rpm speed and was significantly better than any other roller and speed. But in this combination the mold rating is not reduced to much extetnt (6) and hence the combination is not suitable for polishing of blackened sorghum grains.

The minimum quantity of brokens were observed at nylon brush roller at 900 rpm speed and significantly better than any other roller and speed. But this combination is not suitable for polishing of blackened sorghum grains.

The similar trend was observed as regard husk and powder which is not suitable for polishing of black sorghum for the same reason stated above.

Interaction effect of feed rate and speed

The minimum mold (4,6) was observed at 90 kg/h and 120 kg/h at 1200 rpm and was significantly better than other feed rates and speeds (Table 5.8). Thus by using these two feed rate and 1200 rpm speed, the polishing of mold affected sorghum was better.

As regard the whole grains, the significantly maximum quantity of whole grains were observed at 180 kg/h and 900 rpm and was significantly better over others but using this combination, the polishing is not better (mold rating is 5.4) hence the combination is not suitable for polishing black mold sorghum.

The significantly minimum brokens were observed at feed rates 180 kg/h (F4) and was at par with 150 kg/h (F3) at 900 rpm and was better than any other feed rate, but in this case also, the mold rating is 5.4 and 5.2 which indicates no better polishing and hence the combination is not suitable.

The lowest husk and powder was observed at feed rate 180 kg/h at 900 rpm and was significantly better than others. But by using this combination also polishing is not done to much extent and hence the combination is not suitable.

Interaction of roller, feed rate and speed

Table 1.9 depicting three factor interaction means, showing effect of roller, feed rate and speed on mold rating of polished whole grains. The minimum mold (2.33) was observed at R3S2F1 and R3S2F2 and was significantly better than rest of all. Hence the polishing of blackened sorghum by using this combination is better. But as the similar extent of polishing is done by using the greater feed rate F2 (120 kg/h), the capacity of polishing is increased as compared to feed rate 90 kg/h (F1). Thus by using the combination RSS2F2 i.e. roller with emery no. 80, feed rate 120 kg/h and speed of roller 1200 rpm, the blackened sorghum can be better polished reducing mold rating to the tune of 2.33.

The highest quantity of polished whole grains were observed at R4F4S1 (9.754) and followed by R4F3S1 (9.7139) and significantly better than rest of all (Table 1.10). But since the mold rating by using these combinations is not reduced to much extent, these combinations are not useful. The combination at which we get very less mold rating gives the polished grains to the tune of 8.5016 and 8.5603, by using R3F1S2 and R3F2S2, respectively. Thus more amount of polished whole grains are getting by using combination R3F2S2 hence this combination can be considered as better combination for polishing of mold affected sorghum grains.

The minimum brokens were observed at R5F4S2 (0.1276) and was significantly better over rest of all combinations (Table 1.11). But using this combination, the mold rating is 6 which indicates polishing is not done to sufficient extent. The combination by which we are getting very less mold rating i.e. R3F1S2 and R3F2S2 gives the broken to the tune of 0.5943 and 0.5876 which are less hence this combination can be considered better for polishing of blackened sorghum.

The minimum husk and powder (Table 1.12) was observed at R4F4S1 and was at par with R4F4S2, R4F3S1, R4F3S2, R4F2S1, R4F2S2, R5F2S1, R5F3S1, R5F4S1 and R5F4S2 was significantly better over rest of combination. But since the mold rating by using this combination is not reduced to much extent, these combinations are not useful. The combination by using which we are getting very less and similar mold rating gives husk and powder to the tune of 0.6493 and 0.6006 here it indicates that even though the mold rating is reduced to similar extent but since the amount of husk and powder is less by using R3F2S2 (0.6006) as compared to R3F2S1 (0.6943) the combination of R3S2F2 can be considered better for polishing of mold affected sorghum.

The data in Table 1.13 revealed that the 1000 grain mass was slightly reduced from 0.032 to 0.031 kg and hardness was reduced from 5.62 kg to 3.62 kg after polishing mold affected sorghum. The protein content of mold affected sorghum (11.51%) was slightly reduced to 11.35% whereas carbohydrate content was slightly increased form 71.86 to 72.02% after polishing. Various organisms such as *Curvularia lunata, Fusarium spp., Alternaria-alternata, Aspergillus spp., phoma spp., Dreschlera spp.* were observed on the moldy grains. Percent incidence of mycoflora was reduced from 85% to 62% after polishing.

The economic analysis of PKV mini dal mill (modified) used for polishing of mold affected sorghum is given Table 1.14. The cost of mold affected sorghum polishing was worked out to be Rs. 35/q. There is net profit of Rs. 23981/- per annum assuming 60 working days. The break even point and pay back period is 37% and 1.40 years, respectively. Thus the technology is technically feasible and economically viable.

Conclusion

PKV mini dal mill can be used for polishing of mold affected sorghum with 80 no. emery roller and 1200 rpm roller speed at feed rate of 120 kg/h.

Table 1.1 Physical propereties of mold affected grain sorghum (Variety: CSH-9)

Moisture content, %	9.6
1000 grain mass, kg	0.032
Hardness, kg	5.62

Table 1.2 Mold rating scale

Mold rating	Mold, %
1	0
2	1-10
3	11-20

4	21-30
5	31-40
6	41-50
7	51-60
8	61-75
9	>75

Table 1.3 Means ratings for selected characters of mold affected sorghum as influenced by different rollers

Rollers/parameters	R1	R2	R3	R4	R5	SE_D	CD
Mold	5.375	4.041	3.333	6.000	6.000	0.064	0.126
Whole grains	8.633	9.040	8.954	9.611	9.541	0.044	0.086
Brokens	0.550	0.293	0.414	0.200	0.037	0.021	0.042
Husk and powder	0.661	0.401	0.422	0.092	0.161	0.021	0.041

Initial mold rating 7

Table 1.4 Mean ratings for selected characters of mold affected sorghum as influenced by different feed rates

Feed rate/parameters	F1	F2	F3	F4	SE_D	CD
Mold	4.633	4.700	5.066	5.400	0.577	0.113
Whole grains	8.906	9.073	9.238	9.406	0.039	0.077
Broken	0.440	0.360	0.301	0.227	0.1940	0.038
Husk and powder	0.458	0.382	0.313	0.236	0.019	0.037

Table 1.5 Mean ratings for selected characters of mold affected sorghum as influenced by different seeds

Speed/parameters	S1	S2	SED	CD 5%
Mold	5.016	4.883	0.040	0.078
Whole grains	9.392	8.920	0.028	0.054
Brokens	0.233	0.431	0.013	0.026
Husk and powder	0.218	0.477	0.013	0.026

Table 1.6: Two factor interaction means showing effect of roller and feed rate on polishing parameters of black mold sorghum

	Mold rating				Whole grain				Brokens				Husk and powder			
Roller feed rate	F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
R1	5	5	5.5	6	8.239	8.386	8.783	9.126	0.764	0.619	0.447	0.369	0.866	0.768	0.555	0.456
R2	3.5	3.8	3.8	5	8.570	8.994	9.044	9.421	0.397	0.317	0.291	0.267	0.540	0.446	0.403	0.316
R3	2.6	2.6	4	4	8.715	8.872	9.087	9.141	0.505	0.454	0.392	0.305	0.545	0.441	0.377	0.326
R4	6	6	6	6	9.490	9.591	9.663	9.702	0.263	0.200	0.184	0.151	0.119	0.094	0.088	0.067
R5	6	6	6	6	9.336	9.573	9.673	9.640	0.272	0.208	0.192	0.142	0.221	0.163	0.144	0.117
SE+	0.129				0.088				0.043				0.042			
CD@5%	0.253				0.173				0.085				0.083			

Table 1.7: Two factor interaction means showing effect of roller and speed on polishing parameters of mold affected sorghum

Roller/speed	Mold rating		Whole grains		Brokens		Husk and powder	
	S1	S2	S1	S2	S1	S2	S1	S2
R1	5.5	5.2	9.256	8.010	0.241	0.859	0.303	1.019
R2	4.082	4	9.221	8.859	0.242	0.344	0.301	0.501
R3	3.5	3.166	9.249	8.658	0.280	0.548	0.303	0.542
R4	6	6	9.690	9.533	0.163	0.236	0.086	0.081
R5	6	6	9.543	9.538	0.239	0.168	0.081	0.224
SE+	0.091		0.026		0.030		0.030	
CD@5%	0.178		0.122		0.060		0.059	

Table 1.8: Two factor interaction means showing effect of feed rate and speed on polishing parameters of mold affected sorghum

Feed rate/speed	Mold rating		Whole grains		Brokens		Husk and powder	
	S1	S2	S1	S2	S1	S2	S1	S2
F1	4.666	4.6	9.189	8.623	0.317	0.563	0.295	0.620
F2	4.8	4.6	9.300	8.846	0.251	0.468	0.242	0.523
F3	5.2	4.93	9.454	9.022	0.206	0.397	0.207	0.419
F4	5.4	5.4	9.625	9.186	0.157	0.296	0.128	0.345

SE+	0.081	0.056	0.027	0.027
CD@5%	0.160	0.109	0.053	0.053

Table 5.9: Three factor interaction means showing effect of roller, feed rate and speed on mold rating of polished whole grains

Feed rate	F1		F2		F3		F4	
Roller speed	S1	S2	S1	S2	S1	S2	S1	S2
R1	5	5	5	5	6	5	6	6
R2	3.33	3.667	4	3.667	4	3.667	5	5
R3	3	2.33	3	2.333	4	4	4	4
R4	6	6	6	6	6	6	6	6
R5	6	6	6	6	6	6	6	6
SE+	0.182							
CD@5%	0.357							

Table 1.10: Three factor interaction means showing effect of roller, feed rate and speed on quantity of polished whole grains

Feed rate	F1		F2		F3		F4	
Roller speed	S1	S2	S1	S2	S1	S2	S1	S2
R1	9.004	7.475	9.020	7.751	9.340	8.226	9.663	8.588
R2	9.026	8.474	9.093	8.795	9.183	8.906	9.582	9.259
R3	8.929	8.501	9.185	8.560	9.410	8.763	9.474	8.807
R4	9.644	9.336	9.648	9.534	9.713	9.612	9.754	9.649
R5	9.342	9.331	9.554	9.593	9.623	9.604	9.654	9.626
SE+	0.125							
CD@5%	0.245							

Table 1.11: Three factor interaction means showing effect of roller, feed rate and speed on quantity of broken

Feed rate	F1		F2		F3		F4	
Roller speed	S1	S2	S1	S2	S1	S2	S1	S2
R1	0.336	1.192	0.267	0.970	0.195	0.698	0.164	0.575

R2	0.300	0.495	0.270	0.365	0.253	0.330	0.147	0.186
R3	0.416	0.594	0.321	0.587	0.211	0.574	0.174	0.435
R4	0.182	0.345	0.172	0.228	0.151	0.217	0.146	0.156
R5	0.352	0.191	0.228	0.188	0.218	0.166	0.156	0.127
SE+	0.615							
CD@5%	0.120							

Table 1.12: Three factor interaction means showing effect of roller, feed rate and speed on husk and powder

Feed rate	F1		F2		F3		F4	
Roller speed	S1	S2	S1	S2	S1	S2	S1	S2
R1	0.399	1.333	0.395	1.141	0.227	0.833	0.142	0.769
R2	0.400	0.680	0.346	0.546	0.326	0.480	0.133	0.300
R3	0.441	0.649	0.282	0.600	0.257	0.498	0.230	0.422
R4	0.133	0.125	0.086	0.102	0.082	0.094	0.064	0.071
R5	0.125	0.316	0.102	0.225	0.094	0.194	0.071	0.164
SE+	0.021							
CD@5%	0.042							

Table 1.13: Physical properties, protein, carbohydrates and per cent incidence on mycoflora observed in grains before and after polishing

Particulars	1000 grain mass, kg	Hardness, kg	Protein, %	Carbohydrates, %	Mycoflora, %
Blackened sorghum	0.032	5.62	11.51	71.86	85
Polished sorghum	0.031	3.62	11.35	72.02	62

Table 1.14: Cost economics of mold affected sorghum polishing by using PKV mini dal mill (modified)

1.	Cost of PKV mini dal mill, Rs.	39000
2.	Working capital, Rs.	6900
3.	Cost of polishing, Rs./q	3500

4.	Annual net profit, Rs.	23981
5.	Break even point, %	37
6.	Pay back period, year	1.40
7.	Return on investment, %	51.80
8.	Employment generation, mandays/year	120

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