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Testing and evaluation of CFTRI dal mill for pigeonpea (*Cajanus cajan*)

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■ **ABSTRACT :** This study covers the performance study of CFTRI dal mill using UPAS-120 variety of pigeonpea as untreated and treated grains. The machine performance was carried out in term of maximum grains input and output capacity, dehusking efficiency, milling efficiency, dal recovery, quality index. In dry milling method, it was found that the maximum grains input and output capacity were 83.77 kg/h and 54.86 kg/h, respectively. The machine dehusking efficiency, milling efficiency, dal recovery, quality index, were 98.97%, 89.31%, 75.21%, 89.34%, respectively while the pearled grains, broaken, powder, husk and undehusked grains were 4.35%, 2.90%, 5.68% 16.20, and 0.03%, respectively. The power consumption at no load and load conditions were 0.92 and 1.19 kW/h, respectively. Similarly in wet milling method, the maximum grains input and output capacity were 93.21 kg/h and 63.79 kg/h, respectively. The machine dehusking efficiency, milling efficiency, dal recovery, quality index, were 98.90%, 92.83%, 75.21%, 92.93%, respectively while the pearled grains, broaken, powder, husk and undehusked grains are 2.62%, 2.90%, 4.11% 16.23, and 0.10%, respectively. The power consumption at no load and load conditions are 0.92 and 1.03 kW/h, respectively.

■ **KEY WORDS :** Pigeonpea, Wet milling, Dry milling, Dal recovery, Quality index

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Pulses can be described as potentially, the most valuable of the naturally occurring source of protein. India is the largest producer of pulses in the world. In the country pulses are consumed mostly in the form of dal, dehusked and split kernel. Nearly 75% of the total legumes production is converted into the dal. Milling of edible pulses for production of dal is an age old process. Milling procedures vary widely from place to place. Thus, recovery of dal varies from 60-75% depending upon the type of pulses, techniques and mills adopted by the millers. Pulses are a source of supplementary protein in daily diets based on cereals and starchy food for predominantly vegetarian population and for those who cannot afford expensive animal protein. Pulses are, therefore, often regarded as poor men's meat (Mangaraj *et al.*, 2013). They also provide energy, essential minerals, vitamins and several compounds considered beneficial for good health (Sadan *et al.*, 2008). India being the largest producer (18.5 million tons) and processor of pulses in the world also imports around 3.5 million tons annually on an average to meet its ever increasing consumption needs of around 22.0 million tons (Patel, 2015).

The PKV mini dal mill is commercialized and being

used successfully by more than 748 users in India and Sri Lanka. The unit is mainly meant for preparation of pulse splits (dal) from pigeonpea, black gram, green gram, soybean, etc. Efforts were made to study its utility for cleaning of rain affected green gram to enhance its versatility. The rain affected and powdery grains of green gram could be efficiently cleaned and polished using leather roller, by operating the machine at 900 rpm with feed rate of 300 kg/h. The cleaned green gram could fetch 8.3 % higher market price over uncleaned one (Borkar *et al.,* 2014). The grains samples of Tur dal processed through polisher machine have better shine and also it was found that there is improvement in the texture of Tur dal (Bagade *et al.,* 2014). Consumer and environmental concerns over the use of traditional methods during pulse processing and has generated interest in non-chemical alternatives. In these days, the potential of continuous flow microwave heating methods at commercial scale are trying as pretreatment technique for dehulling of pulses because pulse processing industries are still running under batch processing (Dronachari and Yadav, 2015). Conversion of pulses into dal is the third largest food processing industry in the country after rice and wheat milling industries (Garg and Agarwal, 2005). Majority of pulse milling is done at domestic, cottage and small to medium-scale industries. Losses during milling at domestic and cottage levels are high about 10-15% (Lal and Verma, 2007). Microwave heating is a technology that is being used increasingly in the food industry due to its considerable advantages in heat transfer comparing to conventional process (Lombrana *et al.*, 2010). Microwave heating in combination with air-jet impingement or infrared heating decreases the non-uniformity of temperature distribution (Datta *et al.*, 2005). Pulsed microwave heating resulted in more uniform temperature distribution in the samples than the continuous microwave heating (Gunasekaran and Yang, 2007). The experiments conducted to control insects using microwave energy and their study showed that the moisture content in wheat drops by less than one percentage points for exposure times greater than that corresponding to total mortality of the three wheat insects (Hamid *et al.,* 1968). The moisture content of wheat was reduced by two percentage points, while 100% mortality of stored-grain insects was achieved using microwave energy. Variety, agronomic conditions of pulse production, seed size and its maturity and uniformity are few factors which influence the milling out turn. Apart from these factors, conditioning of pulses and machine parameter can cause lower recovery of dal by 10-20 per cent (Vadivambal *et al.*, 2007). Enzyme treatments were found to have no adverse effect on cooking properties of pigeonpea grains. The dal recovery and milling efficiency at optimized independent parameters were 76.60 and 96.19%, respectively (Murumkar *et al.*, 2016).

CFTRI pulse mill consists of cone emery coated roller as its milling unit, which rotates inside conical sieve. Reported milling efficiency of the mill is 78-80 % by weight using standard recommended procedure giving broken 3-5 %. And reported capacity of the mill is 100 kg/h. CFTRI dal mill operates at speed 110 and 450 rpm. The objective of the present investigation was to test and evaluate recovery of dal, brokens, husk, pearled grain, unhusked dal and unhusked grain out of input grain. It also aims to determine the power consumption, speed of milling unit, type and dimensions of belt and pulley, specification as well as other marked audio-visual observation.

METHODOLOGY

Piogeonpea grain of variety UPAS-120 available at IIPR, Kanpur was used for testing and evaluation of CFTRI mill. The grain was cleaned and graded. The oversize and undersize grains were rejected and intermediate size grains were used for conducting pulse milling.

CFTRI Dal mill :

CFTRI dal mill is designed by Central Food Technology Research Institute, Mysore and manufactured by A.M.I. Engg. Patna, Bihar. It is a semi-automatic composite unit consisting of a dehusking unit, aspirator assembly and reciprocating sieving arrangement, all combined together in a manner that the entire system operates by 1hp electric motor. Pulses dehusking system consists of an inverted emery cone fixed to the vertical shaft which can be lowered or raised by clearance adjustment screw with a chuck nut by a wheel. The inverted emery cone is enclosed in a steel wire mesh cone fixed on the main frame of the machine concentric to the emery cone. A gravity control hopper with micro system is provided at the top for smooth flow of pulses into the machine wire mesh cone is covered by

a mild steel sheets cone which does not allow the dust to escape. A suitable steel ladder is provided with the mission that the worker may conveniently pour the pre-milled and graded pulses into the hopper stepping on the ladder. Just below the inverted cone, another cone is provided which as a discharge outlet at the bottom connected to the aspirator assembly having steps of sieves in the same.

Fig. A : CFTRI Dal milling machine

The mill stream from the dehusking unit keep rolling down over the steps of sieves of the aspirator assembly. The husk and the dust are sucked by the suction blower through a pipe and discharged through a outlet into a bag attached to the outlet. The remaining mill stream keep pouring steadily into the reciprocating sieving frame with its forward and backward movements, pours the brokens, dehusked split pulses and the un-dehusked pulses through three separate outlets and containers placed under them. All these functions are performed by the mini dal mill automatically in a single operation.

Milling procedure :

As per recommendation of CFTRI Mysore, raw grains of pigeonpea were cleaned and graded first by CFTRI grader using 3.0 x 19 mm and 6.0 mm sieves. The graded uniform size grains were used for milling under untreated and treated conditions. In treated milling method, whole grains were soaked in tap water for 1 h. After soaking, excess water was drained off and heaped for 3 hours. Grains were sun dried upto moisture content 10% (wb). Then the material was passed through CFTRI mill to carry out dehusking and splitting functions. Materials received at outlet *i.e.* processed material was separated into various fractions using 2.5mm and 3.0 x 19.5mm sieve combination. The over flow grains contained whole unhusked and dehusked grain which were separated manually (Fig. B).

Pre test operations :

Testing of dal mill was followed by some pretest operations under which raw pigeonpea were cleaned, graded, scratched and then conditioning of grain was performed. Just before commencement of test machine was checked and adjusted. These pretest operations are described below.

Cleaning and grading of grain:

Cleaning was carried out by CIAE air screen cleaner to remove light particles like 3.0 x 19 mm chaff, dirt etc. Then grading was done by CFTRI grader. The grains passed through 6.0 mm sieve were used for milling

Table A : Specification of machine

Machine parameter				
Sr. No.	Pullies	Diameter, cm		rpm
1.	Motor pullies	11.5		1425
2.	Emery pulley	30		100
3.	Grader pulley	30		398
4.	Blower pulley	5		2930
	Grading unit			
1.	I screen	Size = 47x24.3 cm^2	Circular holes/cm^2=6	
2.	II screen	Size = 47x24.3 cm^2	Circular holes/cm^2=98	
3.	Strokes	No. of strokes/min.		98
4.	Screen slope (θ)	$\cos\theta = \frac{\text{Project length of sieve at ground}}{\text{Inclind length of seive}} = \frac{112.1}{112.23} = 2.76°$		

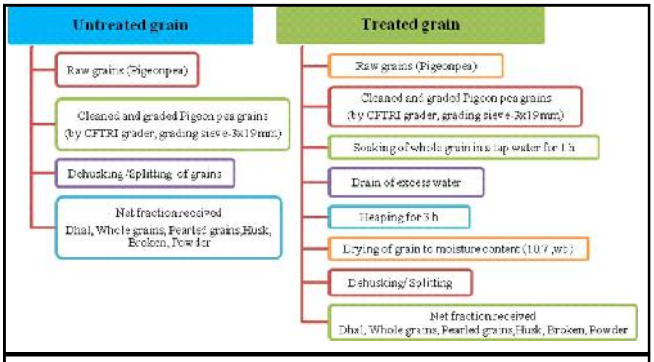

Fig. B : Milling process flow chart of untreated and treated grains

experiments and 3.0 x 19 mm sieve was used to remove small grains and other impurities. Grading was done to obtain uniform grain of pigeonpea.

Pre milling treatment (CFTRI method) :

In conditioning, whole pigeonpea grains were soaked in a tap water for 60 minutes. After soaking excess water was drained off and grains were heaped for 3 hours followed by sun drying of grains upto 10.1% (wb) moisture content. Then milling was carried to perform splitting and dehusking in CFTRI dal mill.

Testing steps and procedures :

The testing of CFTRI pulse mill using piogeonpea grains was performd mainly in three phases namely general testing, test at no load and st at load

General testing :

In this testing the specifications were measured like overall dimension, power unit, milling unit, sieve unit, feeding unit, power transmission system, material of construction etc.

Test at no load :

Under test at no load, mill was allowed to run without giving any input for half an hour at the specified speed of different components. During this period the shaft speed, energy consumption and audio-Visual observations were taken and calculations related to these observations were performed.

Test at load :

Test at load was performed in two phases namely

Table B : Milling parameters

Sr. No.	Parameters	Formula	
1.	Dal recovery (%)	$\frac{\text{Weight of dal after milling}}{\text{Weight of whole grains after milling}} \times 100$	
2.	Pearled grain (%)	$\frac{\text{Weight of pearled grain after milling}}{\text{Weight of whole grains after milling}} \times 100$	
3.	Broken (%)	$\frac{\text{Weight of brokens after milling}}{\text{Weight of whole grains after milling}} \times 100$	
4.	Powder (%)	$\frac{\text{Weight of powder after milling}}{\text{Weight of whole grains after milling}} \times 100$	
5.	Husk (%)	$\frac{\text{Weight of husk after milling}}{\text{Weight of whole grains after milling}} \times 100$	
6.	Undehusked grain (%)	$\frac{\text{Weight of unhusk after milling}}{\text{Weight of whole grains after milling}} \times 100$	
7.	Degree of dehusking (%)	$DD = \frac{\text{Total input weight, g} - \text{Weight of whole undehusked grain, g}}{\text{Weight of whole undehusked grain, g}} \times 100$	
8.	Quality index (QI)	$QI = \frac{F_w}{F_w + B_w + P_w} \times 100$ F_w = Finished product weight (Dehusked split and full grains) B_w = Broken weight, P_w = Power weight	
9.	Milling or dehusking efficiency (%)	$ME = \frac{DD \times QI}{100}$ DD = Degree of dehusking QI = Quality index	
10.	Maximum input capacity (MIC)	$MIC = \frac{\text{Quantity of whole grains fed in inlet of milling unit}}{\text{Time}}$	kg/h
11.	Dal output capacity (DOC)	$DOC = \frac{\text{Dal received at the end of process}}{\text{Time}}$	kg/h
12.	Power consumption	Energy meter was used	kWh

short run load test and long run load test.

Short run test :

In short run load test, machine was kept on level floor and arrangements were made to conduct test under close to still air condition. Firstly machine was run idle for 20 minutes, then material was fed to the machine.

Long run test :

The dal mill was operated with load for 24 hours while 6 hours continuously. During long run load test the points were observed like breakdowns in milling unit, breakdowns in sieving unit, breakdowns in body/frame, loosening of nuts and bolts, unusual heating of bearings or shafts, breakage or slippage of belts, unusual knocking/ rattling sound initially not present.

Analysis of response parameters :

The following milling parameters (Table B) were recorded during the experiment conducted in the IIPR (Indian Institute of Pulse Research) lab:

RESULTS AND DISCUSSION

CFTRI dal milling machine was evaluated for its performance study in terms of dal recovery and energy consumtion. There are several mini dal mills available in Indian market. This machine is suitable for small farmers and entrepreneurs. It comes under semi automatic category of mini dal mills. The results obtained are discussed below under no load and load conditions.

General testing :

In general testing specification, material of construction, visual observation and provision for various adjustments of the mill were checked and measured. The length, width and height of CFTRI dal mill were 1720mm, 840mm and 2025mm, respectively. A 1hp single phase induction motor was used as power unit. Milling unit consists of cone type vertical rotating inside conical spring wire mesh sieve. The emery cone has overall dimensions of base diameter 31.0 cm and height 18.0 cm. Milling clearance at inlet was found 11 mm while at outlet it was found to be 5mm. Milling unit is rotated by a shaft of diameter 3.54 cm. The diameter of pulley attached to motor was 11cm. The sieving unit consists of two rectangular sieves each having overall size of 47x24.3 cm. For grading of pigeonpea dal, combination of circular sieve of 2.5 mm dia, 6 numbers of hole per cm^2 and rectangular sieve with 19x3mm size and 2 numbers of hole per cm^2 were found most effective. Sieving is attached to milling unit and supported on frame at a slope of 2.75^o. The speed of milling unit was used 100 rpm and was fixed.

Grain feeding trough have size 43x43 cm at the upper end and 8x8 cm at the lower end. Feeding trough is located at a height of 266 cm above the ground level. Batch type direct pouring is possible in feeding trough. Different components of the machine are constructed of various materials. Frame is made of mild steel while feeding trough is made of mild steel sheet. Milling unit *i.e.* cylinder is made of carborandum and is coated by emery. Main shaft is made of high carbon steel and pulley is made of cast iron. B-Belts are used which are made

Table 1 : Test data of untreated pigeonpea grains

Sr. No.	Parameters		Sample I	Sample II	Sample III	Average values
1.	Dal recovery (%)		77.84	74.40	73.39	75.21
2.	Pearled grain (%)		4.76	4.46	3.82	4.35
3.	Broken (%)		2.41	2.70	3.60	2.90
4.	Powder (%)		3.35	4.29	9.39	5.68
5.	Husk (%)		16.20	16.03	16.36	16.20
6.	Undehusked grain (%)		0.03	0.02	0.03	0.03
7.	Degree of dehusking (%)		98.97	98.98	98.97	98.97
8.	Quality index		92.6	89.79	85.62	89.34
9.	Milling efficiency (%)		92.57	89.77	85.59	89.31
10.	Maximum input capacity (kg/h)		95.54	76.42	79.36	83.77
11.	Dal output capacity (kg/h)		66.03	51.05	47.49	54.86
12.	Power consumption	at no load	0.28 kW	0.32 kW	0.32 kW	0.92 kW/h
	/20minuts	at load	0.36 kW	0.40 kW	0.43 kW	1.19 kW/h

of rubber. Sieve is constructed by perforated sheet metal. In CFTRI dal mill no provision is given for transportation. The machine provides easy replacement and cleaning of sieve. Protection of bearings against the ingress of dust is adequate while safety arrangements specially at moving parts are not adequate. Belt tightening is possible by adjusting motor position. Milling clearance can be adjusted as per crop requirement. Feed rate can be adjusted by making variations in opening of inlet. Milling shaft can adjusted for two speeds. Sieve slops are fixed but sieve combinations can be varied as per crop requirement.

Test at no load :

During test at no load the machine was run for 30 minutes and readings of energy meter were taken after each 5 minutes. The power consumption in 30 minutes was noted to be 0.450 kWh. Finally, the power consumption at no-load was found 0.90 kW/h. There was not any marked oscillation/vibration, undue knocking or rattling sound, unusual wear or slackness in any component. The shafts were running properly/smoothly in their respective bearings, there was not any marked rise in temperature of the bearings as well as belt was functioning properly.

Test at load :

The results of test at load are discussed in two phases namely (i) Short run load test and (ii) Long run load test. These tests were conducted for untreated and water treated grains.

The machine was tested for its performance using untreated and treated pigeonpea grains. The moisture content of untreated and treated pigeonpea grains were 8.9% (wb) and 10.1% (wb), respectively. Five kg sample was fed in to hopper as triplicate during the experiment and the performance data were recorded are as follows:

Untreated grain :

Table 1 shows that the maximum grains input and output capacity were 83.77 kg/h and 54.86 kg/h, respectively. The machine dehusking efficiency, milling efficiency, dal recovery, quality index, are 98.97%, 89.31%, 75.21%, 89.34%, respectively while the pearled grains, broaken, powder, husk and undehusked grains were 4.35%, 2.90%, 5.68% 16.20, and 0.03%, respectively. The power consumption at no load and load conditions were 0.92 and 1.19 kW/h, respectively.

Treated grains :

Table 2 shows that the maximum grains input and output capacity were 93.21 kg/h and 63.79 kg/h, respectively. The machine dehusking efficiency, milling efficiency, dal recovery, quality index, were 98.90%, 92.83%, 75.21%, 92.93%, respectively while the pearled grains, broaken, powder, husk and undehusked grains were 2.62%, 2.90%, 4.11% 16.23, and 0.10%, respectively. The power consumption at no load and load conditions were 0.92 and 1.03 kW/h, respectively.

Long run test :

The machine was run for 24 hours during the long run test in which the machine was run for the 6 hours continuously. The machine gave poor output capacity

Table 2 : Test data of treated pigeonpea grains

Sr. No.	Parameters		Sample I	Sample II	Sample III	Average values
1.	Dal recovery (%)		77.84	74.40	73.39	75.21
2.	Pearled grain (%)		3.84	2.54	1.47	2.62
3.	Broken (%)		2.41	2.70	3.60	2.90
4.	Powder (%)		3.66	4.08	4.58	4.11
5.	Husk (%)		16.24	16.10	16.36	16.23
6.	Undehusked grain (%)		0.10	0.16	0.04	0.10
7.	Degree of dehusking (%)		98.90	98.83	98.96	98.90
8.	Quality index		96.67	91.89	90.22	92.93
9.	Milling efficiency (%)		96.57	91.73	90.18	92.83
10.	Maximum input capacity (kg/h)		94.63	87.71	97.29	93.21
11.	Dal output capacity (kg/h)		66.97	59.46	64.94	63.79
12.	Power consumption	at no load	0.28 kW	0.32 kW	0.32 kW	0.92 kW/h
	/20minuts	at load	0.341 kW	0.344 kW	0.343 kW	1.028kW/h

due to clogging problem which occurred consistently whenever the feed rated was tried to increase. There was no problem of break downs in milling unit, sieving unit and body/frame and no need of any major or minor repairing during milling.

Conclusion :

CFTRI dal mill was tested for its performance evaluation using UPAS-120 variety of pigeonpea. Dry and wet milling methods were used in this study. In dry milling method, after complete analysis and evaluation of all parameters it was found that the maximum grains input and output capacity were 83.77 kg/h and 54.86 kg/h, respectively. The machine dehusking efficiency, milling efficiency, dal recovery, quality index, were 98.97%, 89.31%, 75.21%, 89.34%, respectively while the pearled grains, broaken, powder, husk and undehusked grains were 4.35%, 2.90%, 5.68% 16.20, and 0.03%, respectively. The power consumption at no load and load conditions were 0.92 and 1.19 kW/h, respectively. Similarly in wet milling method, the maximum grains input and output capacity were 93.21 kg/h and 63.79 kg/h, respectively. The machine dehusking efficiency, milling efficiency, dal recovery, quality index, were 98.90%, 92.83%, 75.21%, 92.93%, respectively while the pearled grains, broaken, powder, husk and undehusked grains were 2.62%, 2.90%, 4.11% 16.23, and 0.10%, respectively. The power consumption at no load and load conditions were 0.92 and 1.03 kW/h, respectively.

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