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Development of Chironji Nut (*Buchanania lanzan*) Grader-cum-Decorticator

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Abstract: PDKV Chironji nut Grader cum Decorticator (CNGD) machine consists of grading hopper, decortication hopper, sieve assembly, outlets, and motor.The performance evaluation for Grading unit was optimized with 39 experiments. The performance evaluation for Decortication unit were optimized with 29 experiments. The experiments were generated through Box-Behnken Design and the experimental data was analyzed by applying Response Surface Methodology (RSM) using Design Expert 12.0.8.0 software for optimising the input parameters. The optimized input parameters of700 rpm oscillating speed of sieve assembly, 180 kg/h feed rate and three sieves each of diameter 9 ,7 and 5mm showed the grading efficiency of 98.81%. The optimized input parameters of8% wb moisture content of nut, 80kg/h feed rate, 750 rpm speed of disc and 8 mm clearance between pair of stone disc showed the decortication efficiency of 76.87%.The developed chironji nut grader cum decorticator would help the cooperative farmers, tribal people, small help groups and unemployed youths for becoming an entrepreneur.

Keywords*:* Chironji, Decorticator, Grader, Value addition, Whole kernel, Capacity, Efficiency

Buchanania lanzan (chironji) belongs to family Anacardiaceae and is commercially very useful. Chironji originated in the Indian sub-continent and is found growing naturally as wild stands in the tropical deciduous forests of north, western and central India mostly in the states of Madhya Pradesh, Bihar, Orissa, Andhra Pradesh, Chhattisgarh, Jharkhand, Gujarat, Karnataka, Varanasi, Rajasthan, Maharashtra and Uttar Pradesh. Chironji kernels have great medicinal values. The whole kernel is used in sweets, meats, expectorant and tonic. Chironji kernels contain 52% oil which is used for treating skin diseases and considered as a substitute for almond oil in traditional medicine preparations. Kernel is rich in nutrients and an active source of crude protein, crude fat, carbohydrates, crude fiber and other rich nutrients like phenolics, natural antioxidants, fatty acids and minerals (Kumar et al 2009). In manual chironji nut decortication process, there is very less recovery of whole kernel and remaining is nearly broken or mashed. There is excessive loss due to crude methodology adopted, which leads not only to huge economical loss but also loss of nutrition (Kumar et al 2009). Traditional processing method of chironji is very cumbersome, time consuming and labour extensive and becomes difficult to get labour for this operation. Thus, in order to get good recovery of chironji kernels, the processing costbecomes higher (Singh et al 2016). The presence of hard seed coat is one of the problem in decortications of nuts. The variation in the dimension of chironji nut also affects the whole kernel recovery. The improper decortications prove to damage the kernel during storage and spoil the kernel. Thus, reduction in shelf life of chironji kernel is observed giving low economic value (Dwived et al 2012).Therefore, the present study was carried out with two objectives development of chironjinut grader cum decorticator and performance evaluation of chironjinut grader cum decorticator.

MATERIAL AND METHODS

The chironji nuts were procured from local farmers of Patur Tehsil of Akola district and Gadchiroli district. PDKV chironji nut grader cum decorticator machine was developed consist of grading hopper, decortication hopper, sieve assembly, outlets, and motor (Plate 1). The optimized experimental design and performance evaluation of grading unit (39 experiments) (Table 1) and decortication unit (29 experiments) (Table 2) of chironjinut grader cum decorticatorwere generated through Box-Behnken Design and the experimental data was analyzed by applying Response Surface Methodology (RSM) using Design Expert 12.0.8.0 software.

A. Experimental Design and Performance evaluation of Grading Unit (Table 1& 2):

The type of oscillating speed of sieve assembly, feed rate and sieve sets (different combinations) were optimized for maximum grading efficiency of chironji nuts

Independent variables:

a. Oscillating speed of sieve assembly, rpm (600, 650, 700, 750 and 800)

b. Feed rate (F), kg/h60, 120, 180, 240 and 300

c. Sieve sets (different combinations)

First sieve set- (Three round hole sieves - dia. as – 9 mm (T), 7mm (M) & 5mm (B)

Second sieve set- Three round hole sieves- dia. as – 8 mm (T), 7mm (M) & 5mm (B)

Third sieve set - Three round hole sieves – dia. as – 8 mm (T), 6mm (M) & 5mm (B)

Dependent variables:

a. Grading Efficiency

The extraction efficiency was calculated using the following formula.

Grading efficiency, % = 100 – un-graded nuts

$$\text{Un – graded nuts (\%)} = \frac{\text{Weight of un – graded nuts, g}}{\text{Weight of total nuts input, g}}$$

Plate 1. Chironji nut grader cum decorticator

Table 1. Levels of independent variables for chironji nut decortication

Independent variables	Symbols		Levels			
	Coded	Un-coded	Coded			Un-coded
Moisture content (% wb) of chironji nut	x_1	M	1	0	-1	9, 8, 7
Feed rate (kg/h)	x_3	F	1	0	-1	100, 80, 60
Speed of Disc (rpm)	x_2	S	1	0	-1	800, 750, 700
Clearance between pair of discs, mm	x_4	C	1	0	-1	10, 8, 6

Table 2. Effect of independent parameters on grading efficiency of chironji nut

Source	Sum of squares	df	Mean Square	F-value	p-value	
Model	418.89	6	69.81	48.91	< 0.0001	Significant
A- Oscillating speed of sieve assembly, rpm	0.3573	1	0.3573	0.2503	0.6203	
B- Feed rate, kg/h	1.67	1	1.67	1.17	0.2851	
C- Sieve sets (Different combinations)	228.20	2	119.75	83.90	< 0.0001	
A^2	50.96	1	50.96	35.71	< 0.0001	
B^2	141.31	1	141.31	99.00	< 0.0001	
Residual	45.67	32	1.43			
Lack of Fit	41.30	19	1.64	1.47	0.2394	Not significant
Pure Error	14.47	13	1.11			
Cor Total	337.56	38				
Std. Dev.	1.19					
Mean	94.55					
C.V. %	1.24					
R^2	0.9268					
Adjusted R^2	0.8963					
Predicted R^2	0.8612					
Adeq Precision	11.0773					

B. Experimental Design and Performance evaluation of Decortication Unit (Table 3 & 4):

Response-surface methodology comprises of methods used for exploring the optimum operating conditions through experimental methods. The levels of independent variables for chironji nut decorticator unit are given in table 3.

Dependent variables:

1. Coefficient of hulling/decortications (E_h)

The coefficient of hulling/decortications was calculated by using the formula given by Sahay and Singh (2002) and Kachru et al (1919).

$$E_h = 100(1-\frac{n2}{n1})$$

where,

n_1 = weight of unhulled nuts before decortication

n_2 = weight of unhulled nuts after decortication

1. Coefficient of wholeness of kernel (Ewk):

The coefficient of wholeness of kernel was determined by using the formula computed by Sahay and Singh (2002) and Kachru et al (1991).

$$E_{wk} = \left(\frac{(k2-k1)}{(k2-k1)+(d2-d1)+(m2-m1)}\right)$$

where,

k_1, k_2 = weight of whole kernels before and after decortication

d_1, d_2= weight of broken kernels before and after decortication

m_1, m_2 = weight of mealy waste before and after decortication

3. Decortication efficiency η (%):

The coefficient of wholeness of kernel was determined by using the formula computed by Sahay and Singh (2002), Kachru et al (1991).

$$\eta\ (\%) = E_h \times E_w$$

RESULTS AND DISCUSSION

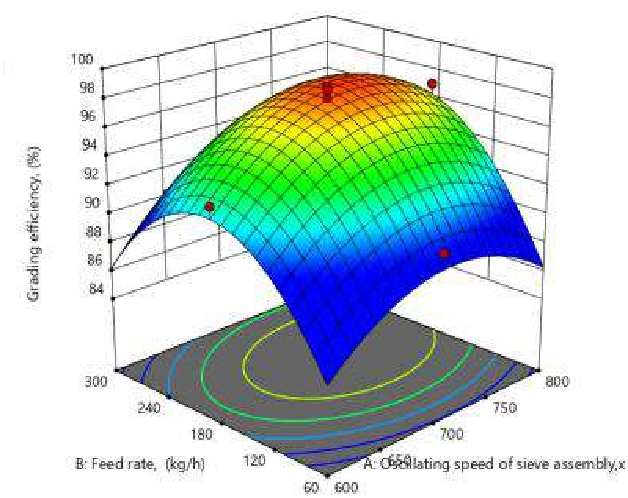
The experimental trials were conducted to optimize the input parameters and evaluated the performance. The maximum and minimum grading efficiency was observed to be 98.81 and 87.02%. For grading efficiency, the model F-value of 48.91 implies that the model was significant. The linear terms oscillating speed of sieve assembly, feed rate and different sieve sets were found to be significant. The lack of fit F-value was which indicates that the developed model is adequate for predicting the response. Moreover, the predicted R^2 of 0.8612 was in reasonable agreement with adjusted R^2 of 0.8963. This revealed that the non-significant terms have not been included in the model. Therefore, this model could be used to navigate the design space. High value of coefficient of determination (R^2 = 0.9268) obtained for response variable indicated that the developed model for grading efficiency accounted for and adequately explained 92.68 % of the total variation.

The feed rate increased, the grading efficiency increased up to certain level and as the feed rate increased beyond significant level, the grading efficiency was decreased in all sieve sets. This might be due to excess raw material above certain limit created hindrance for rubbing action between sieves and the nuts. This resulted in less grading at higher feed rates.

The experimental trials were conducted to optimize the input parameters and evaluated the performance. The maximum and minimum decortication efficiency was observed to be 77.19% and 51.84% Response Surface Methodology (RSM) was applied to the experimental data using the package, Design- Expert version 12 (Statease Inc, Minneapol was, USA, Trial version, 2018).

The Model F-value 16.50 implies that the model was significant Table 4. There was only a 0.01% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms were significant. In this case A, B, C, D, A², B², C², D² were significant model terms. Values greater than 0.1000 indicate the model terms were not significant. The Lack of Fit F-value of 5.08 implies there was 6.56% chance that a Lack of Fit F-value this large occurred due to noise. Non-significant lack of fit was good and thus, the model was fit for obtaining the response.

The R^2 value was computed by a least square technique and 0.9429 showing good fit of model to the data. The



The optimized input parameters for grading efficiency of chironji nut were found to be:

1) Oscillating speed of sieve assembly, rpm = 701.518 ~ 700
2) Feed rate (kg/h) = 176.891~ 180
3) Type of sieve set = first sieve set [three round hole sieves with diameter as – 9 mm (T), 7mm (M) and 5mm(B)]

Fig. 1. Effect of oscillating speed of sieve assembly and feed rate on grading efficiency of chironji nut (first sieve set)

Predicted R^2 of 0.6883 was in reasonable agreement with the Adjusted R^2 of 0.8857 i.e. the difference was less than 0.2. Adeq. Precision measures the signal to noise ratio. A ratio greater than 4 was desirable. Ratio of 12.893 indicated an adequate signal. So this model was used to navigate the design space (Table 5 & Fig. 3)

The feed rate of 80 kg/h was sufficient for getting maximum decortication efficiency as feed rate allowed the free flowing of nut for decortication without any type of clogging in hopper and pair of disc. It was observed that, at the speed of disc 750 rpm and 8 mm clearance between pair of disc were best combination for getting maximum decortication efficiency. Experiments reveled that, as the speed was decreased then, more undecorticated nuts were obtained and when the speed was increased then more brokens were obtained. Thus, the process and machine parameters *viz.* moisture content 8 % wb, feed rate 80 kg/h, speed of disc 750 rpm and clearance between pair of disc 8 mm were the best combination of variables for getting maximum decortication efficiency.

Table 3. Analysis of variance (ANOVA) showing the effect of process and machine parameters on decortication efficiency

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	1695.81	14	121.13	16.50	< 0.0001	Significant
A-Moisture Content	261.80	1	261.80	35.66	< 0.0001	
B-Feed Rate	48.84	1	48.84	6.65	0.0218	
C-Speed of Disc	65.10	1	65.10	8.87	0.0100	
D-Pair of Disc	73.56	1	73.56	10.02	0.0069	
AB	0.7569	1	0.7569	0.1031	0.7529	
AC	0.0506	1	0.0506	0.0069	0.9350	
AD	12.11	1	12.11	1.65	0.2199	
BC	0.0036	1	0.0036	0.0005	0.9826	
BD	6.43	1	6.43	0.8753	0.3653	
CD	11.63	1	11.63	1.58	0.2288	
A^2	157.09	1	157.09	21.40	0.0004	
B^2	509.33	1	509.33	69.38	< 0.0001	
C^2	264.55	1	264.55	36.03	< 0.0001	
D^2	830.64	1	830.64	113.14	< 0.0001	
Residual	102.78	14	7.34			
Lack of Fit	95.28	10	9.53	5.08	0.0656	Non significant
Pure Error	7.50	4	1.88			
Cor Total	1798.59	28				
Std. Dev.	2.71		R^2	0.9429		
Mean	63.16		Adjusted R^2	0.8857		
C.V. %	4.29		Predicted R^2	0.6883		
			Adeq.Precision	12.8929		

Table 4. Optimization criteria for different process variables and responses for chironji nut decortication

Name	Goal	Lower limit	Upper limit
Moisture content (% wb)	is in range	7	9
Feed rate (kg/h)	is in range	60	100
Speed of disc (rpm)	is in range	700	800
Clearance between pair of disc (mm)	is in range	6	10
Coefficient of decortication	Maximum	79	94
Coefficient of wholeness of kernel	Maximum	0.61	0.83
Decortication efficiency (%)	Maximum	51.84	77.19

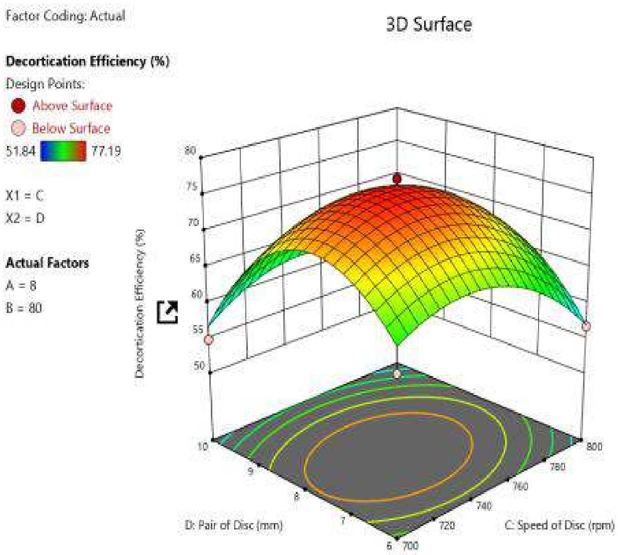
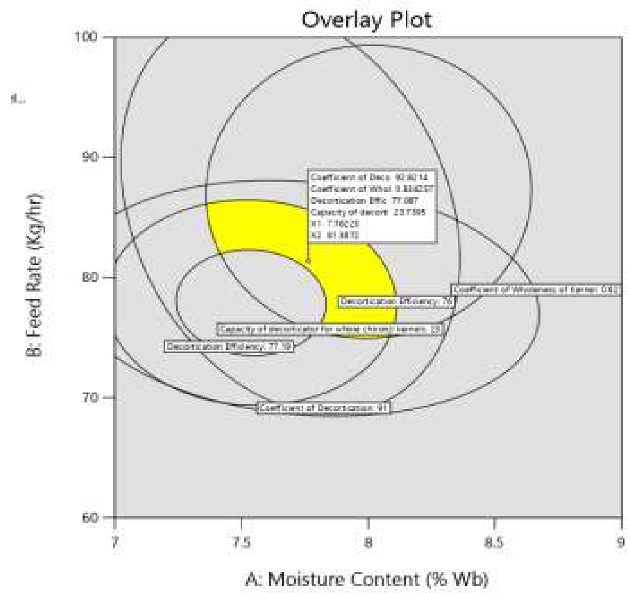


Fig. 3. Effect of SOD and POD on decortication efficiency at MR=8% (wb) and FR=80Kg/h

Optimization of different process input variables for chironji nut decortications: A stationary point at which the slope of the response surface was zero in all the direction was calculated by partially differentiating the model with respect to each variable, equating these derivatives to zero and simultaneously solving the resulting equations, thus simultaneously optimizing the multiple responses. The desired goals for each factor and responses were chosen in Table 6.

CONCLUSIONS

The developed PDKV Chironji nut Grader cum Decorticator has a grading efficiency of 98.81 and decortication efficiency 76.87 per cent.



The optimum values of operational variables obtained by numerical optimization (Fig. 5)
Moisture content, % wb = 7.65 ~ 8
Feed rate, kg/h = 83.46 ~ 80
Speed of disc, rpm = 734.60 ~ 750
Clearance between pair of disc, mm = 7.92 ~ 8

Fig. 4. Effect of moisture content (MR) and feed rate (FR) on various responses

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