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Optimization of milling parameters of green gram in sub-tropical climate using Response surface methodology: A study in Andaman and Nicobar Islands

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Abstract

This study was carried out to investigate the effect of oil concentration and drying time on the milling efficiency of green gram in sub-tropical climate. Optimization of machine parameters using response surface methodology (RSM) greatly overcomes the numbers of experimental trials generally undertaken apart from maximizing the output of the system. A quadratic model satisfactorily described the milling efficiency and dal recovery for the tested dal mill. There was no significant reduction of broken and powder were found during the experimentation. The process parameters showed significant effects ($p<0.05$) on milling efficiency. The result indicated that for the optimum condition, 0.68% of oil concentration and 2.47 days of drying helps in recovering higher hulling efficiency as well as dal recovery.

Keywords: *Green gram, milling efficiency, dal recovery, optimization, response surface methodology*

Introduction

Pulses along with cereals play a vital role in human nutrition (Tiwari *et al.*) and also regarded as poorman' protein (Mangaraj, 2009). Among pulse crops, green gram (*Vigna radiata* L. Wilczek) is an important pulse crops in India which is well known for their nutritional and functional value (Gowen *et al.*, 2008). It is rich sources of essential amino acids, such as lysine and contain health-promoting phytochemicals (Berrios *et al.*, 1999). Their nutritional composition includes complex carbohydrates (e.g. fibre, resistant starch and

minerals like folate and iron as well as antioxidants and only very small amounts of fat. In India, about 80 % of the pulse production is consumed in form of dal or powder and remaining 20 % as the whole seed and other forms (Chacko *et al.*,

dal by various methods/ processes. The recovery of dal varies from 60 % - 75 %, depending upon the type of pulses and techniques adopted by the millers such as methods of pre-treatment and milling machinery used (Sahay and Bisht, 1988). Processing of green gram has several problems as green gram is difficult to mill due to the presence of vitreous layer of gums and mucilage's, which makes it difficult in dehusking of green gram. Dehusking is a process that reduces the fiber content and improves appearance, texture, cooking quality, palatability and digestibility of grain legumes. Rewetting/ oil treatments and drying is done to loosen portions of husk sticking after repeated rolling. To facilitate dehusking and splitting of pulses alternate wetting and drying method is used. To obtain complete dehusking of the grains a large number of abrasive forces is applied in this case as a result high losses occur in the form of broken and powder for proper dehusking, Premilling treatments are given to ease the removal of husk. Premilling treatments are given to affect the gums present in-between seed coats and cotyledon in order to (a) loosen the husk, (b) ease milling, (c) reduce breakage and (d) improve the quality of split.

Various workers have tried different premilling treatments to loosen the hull. There are two approaches to remove hulls, namely wet and dry milling. Generally, the dry method of milling is used throughout the Indian subcontinent for milling of pigeon pea because the quality of splits obtained from wet milling is poor (Kurien &

seed size and different pre-treatments on splitting and dehulling of lentil (Lens culinaris) and reported that dehulling efficiency was highest with low seed moisture content. Kurien *et al.*, (1881) reported that dehulling of pigeon pea can be rendered easier by prolonged soaking in water for 12h or more, but the dal so obtained remains uncooked and tough even with prolonged boiling. The maximum dehulling efficiency for pigeon pea was obtained at 10.1% moisture content (db), dehulling time 12.3s and mustered oil treatment 0.3% (Goyal *et al.*, 2008). Ehiwe (1986) studied the dehulling quality of cowpea, pigeon pea, and green gram cultivars with the tangential abrasive dehulling device and reported that seed size was the most important factor affecting the dehulling process. Oil application is traditionally practiced and is still in vogue (Narasimha *et al.,* 2004). Chemical treatment with sodium bicarbonate, sodium carbonate, sodium hydroxide or acetic acid has been tried in lieu of vegetable oil. These studies revealed that the removal of the hull was made easier by treatment with mustard oil as well as with *sirka* (vinegar), and subsequent heating at 60^{o}C for 30 min milling yields obtained with sirka pre-treatment and with mustard was 77.47 and 75.10 %, respectively (Krishnamurthy *et al.,* 1972). The effect of one normal solution sodium bicarbonate on the dehulling of pigeon pea was reported to be 87.92% (Saxena *et al.,*1990). Treatment with urea solution applied to both non scarified and scarified grain and its effect on the dehulling of pigeon pea were reported by Phirke and Bhole (2000). Studies on premilling treatment performance and quality of resultant *dhal* are limited. Tiwari *et al*., (2005) observed an 85.5 % dehusking loss and a 6.98 % powdering loss in black gram at 0.8 % oil treatment with 90^{o}C drying temperature.

pigeon pea to obtain maximum recovery. Mangaraj *et al*., 2009 reported that the roller peripheral speed of 9.6 m/s, emery grit size 1 mm, and feed rate 111 kg/h were optimal for getting higher hulling efficiency and dal recovery. The method of dehulling significantly affects the formation of broken and powdered particles and in the case of pigeon

for powder (Singh *et al*., 1992).

Andaman and Nicobar Islands is located at 11° 40’ N and 92° 46’ E where pulses are confined to northern part of the region. In these Islands, nearly 85% of the pulses are transported to mainland (India) through ship for processing whereas the same pulses after processing fetch at higher prices at the local market. Moreover, the status of post-harvest processing is very low because of tropical climate with humidity of 75-95% year round and temperature of 22-32^{0}C which harbours microbial loads at the harvested/ stored products compared to other parts of the country. As the Islands to home to most of the south Indian and Bengali immigrant, green gram is hugely consumed by them in the form of Dal, Sambhar etc. As sun drying is practiced the traditional method is not only weather dependent but also it requires a large drying yard to match with the milling capacity. As a result it takes 3 to 7 days for complete processing of a batch of 20 to 30 tonnes of pulses into dhals. Moreover milling losses are also quite high in the traditional method of milling of pulses. In this regard, to mitigate the problems faced by the Island farmers, a dal mill was purchased from AICRP on PHT centre, Akola and tested at CIARI, Port Blair with respect to effect of sun drying and oil as a pretrement on the milling characteristics of green gram.

Material and methods

Fresh green grams were procured from local market and after cleaning, the moisture content of the grain was determined using the oven-drying method (AOAC, 2000). Then, the samples were dried under the sun to decrease the initial moisture content from 13 % (w.b) to the desired moisture content of 9- 10% (wb) for milling. These were first graded in the pulse grader with rectangular slots of dimensions 4 · 30 mm. 1 kg of first grade green gram was taken in vessel and oil was applied at required concentrations (0%, 0.2%, 0.4%, 0.6%, 0.8% and 1%) and was mixed manually. These oil treated samples were dried for desired time (1, 2 and 3days) as per design procedure (Table 1).

Table 1: Coded level of independent variables used in the experiments

Independent variables	Coded level				
	-1.41α	-1	0	+1	+1.41α
Oil concentration (%)	-0.20	0	0.5	1	1.20
Drying time	0.585	1	2	3	3.41

Milling procedure

Dehusking was performed in laboratory model dal mill. The machine consists of four units viz. dehulling unit (emery roller), separation unit, splitting unit and screw conveyor. It requires 3-hp single phase electric motor for complete operation. The horizontal cone type abrasive roller is provided for dehulling of grain with the provision of inlet and outlet control. Out of dehulled mixture, powder and husk are separated by an aspirator and come out through cyclone separator. The remainder mixture fall down by gravity on the reciprocating sieve unit provided with two sieves. The upper sieve separates grain with gota and lower separates dal. The brokens are collected below sieves on pan. The grain with gota is fed to the screw conveyor where either oil or water can be uniformly applied to the pulses. After 2-3 passes, gota can be splitted by an elevator after water treatment and drying. After dehusking, different fractions were collected and graded as separate whole, splits, powder and brokens. Dehusked and husked samples were separated by taking 50 g of composite sample and analysed visually to separate dehusked and husked grains and were tabulated as whole dehusked, whole unhusked, dehusked split, unhusked split, brokens, and husk and powder. All samples were studied in triplicates.

Hulling efficiency (HE) was calculated based on the formula given by Kuprits (1967).

$$HE = C_h \ x \ C_{wk} \ x 100 \quad (1)$$

Where Ch is the coefficient of hulling and Cwk is the coefficientof wholeness of kernel;

$$C_h = 1 - \frac{W_{uh}}{\cdots}$$

$$C_{wk} = \frac{W_{fp}}{W_{fp} + W_{br} + W_{po}}$$

Dal recovery (DR) can be calculated using following equation

$$DR = \frac{W_{fp}}{W_g - W_{uh}} \quad (2)$$

Where W_g is the weight of grain fed to the system, W_{uh} is the weight of unhulled grain after milling, W_{th} is the weight of grains used for milling, W_{fp} is the weight of finished product, W_{br} is the weight of brokens and W_{po} is the weight of powder.

Experimental design

The variables chosen for milling experiments were oil concentration and drying time. The variable levels were selected on the basis of preliminary drying experiments. he independent variables fixed at 3 level (drying time in days) and 5 level (oil concentration) as per Central Composite Rotatable Design (CCRD) and a total number of 13 experiments were carried out as evident from Table 1. The experiments were conducted in a randomised order to minimise the effect of unexpected variability in the observed responses due to extraneous factors. For each factor, the experimental range and the central point were based on the results of preliminary trials. Independent variables, their values and the coded factor . Five repeated experiments were conducted at the central points of the coded variables to calculate the error sum of squares and the lack of fit of the developed regression equation between the responses and independent variables (Myres 1971). Response surface methodology (RSM) was used to determine the relative contributions of oil concentration and drying time to various responses under study such as hulling efficiency (H.E) and dal recovery (D.R). The main advantage of the RSM is it reduces the number of experiments needed to evaluate multiple parameters and their interactions. The second-order polynomial response surface model (Eq. (1)) was fitted to each of the response variables (Yk).

$$Y_k = b_{k0} + \sum_{i=1}^{2} b_{ki} X_i + \sum_{i=1}^{2} b_{kii} X_i^{\,2} + \sum_{i \neq j=1}^{2} b_{kij} X_i X_j$$

(3)

Where, b_{k0}, b_{ki}, b_{kii} and b_{kij} are constant, linear, quadratic and cross-product regression coefficients of the model, respectively; Xi and X_i^2 represent the independent variables.

Table 2. Combination of treatments with two variable second-order RSM design

Experiment No. (Treatment)	Oil (%)	Drying time (days)	Broken (%)	Powder (%)	Hulling efficiency (%)	Dal recovery (%)
1	0.5 (0)	0.585 (-1.41)	4.3	6.8	57.97	49.46
2	0.5 (0)	2 (0)	6.5	7.9	82.62	72.85
3	0 (-1)	3 (1)	5.9	8.7	57.47	51.77
4	0.5 (0)	3.41 (1.41)	4.6	6.7	89.42	78.61
5	1.20 (1.41)	2 (0)	6.8	7.2	70.52	64.98
6	0.5 (0)	2 (0)	5.7	6.9	79.32	73.17
7	0.5 (0)	2 (0)	5.9	7.3	78.54	70.48
8	0 (-1)	1 (-1)	4.3	6.8	57.48	52.47
9	0.5 (0)	2 (0)	6	7.7	78.54	69.48
10	0.5 (0)	2 (0)	5.5	6.9	79.12	69.79
11	1 (1)	1 (-1)	7.4	10.7	67.79	59.74
12	-0.20 (-1.41)	2 (0)	6.9	11.4	56.41	49.18
13	1 (1)	3 (1)	10.2	12.7	72.98	64.81

Analysis of Data

Response surface analysis was applied to the experimental data (Table 2), and the second-order polynomial response
to each of the response variables (H.E and D.R). Regression analysis and analysis of variance (ANOVA) were conducted for fitting the model and to examine the statistical significance of the model terms. The estimated regression coefficients of the quadratic polynomial models for the response variables, along with the corresponding R^2 and coefficient of variation (CV) values were carried out using a commercial statistical package Design Expert, version 9.0.6 (Stat Ease Inc., Minneapolis, MN). The adequacies of the models were determined using model analysis, lack-of-fit test, and R^2 (coefficient of determination) analysis as outlined by Lee *et al*. (2000) and Weng *et al*. (2001). If there is a significant lack of fit as indicated by a low probability value, the response predictor is discarded. Response surfaces were generated

and the corresponding numerical optimization was performed.

Optimization Technique

Numerical optimization technique of Design Expert 9.0.6 was used for simultaneous optimization of the multiple responses. The desired goals for each factor and response were chosen which are already discussed in the optimization of dal mill.

Results and discussion

Effect of oil concentration and drying time was observed on the dehusking of green gram, in case of control where green gram was not treated with oil but dried at different drying time. It was estimated that this particular variety was having husk percentage of 9.5 %. Husk percentage was estimated by carefully removing the husk and the germ part was separated from cotyledons by using a sharp knife and it was found while milling the germ portion and the husk was removed in case of whole dehusked grains and also in case of dehusked splits. From

one of the important steps for proper dehusking of green gram. Analysis of variance showed that all the models were significant ($p<0.05$) for all the responses (Table 2). The lack of fit (Table 2), which measures the fitness of the model, did not result in a significant F value for pigeon pea dal recovery and milling efficiencies, indicating that these models are sufficiently accurate for predicting those responses.

Table 2 Regression coefficients of the second-order polynomial model for the response variables (in actual units)

	Dependent parameters			
	Estimated coefficient		F-Value	
Variables	H.E	D.R	H.E	D.R
model	--	--	6.84**	6.88**
Constant	79.63	59.31		
Oil concentration (X1)	5.72	3.53	7.27**	7.77**
Drying time (X2)	6.21	5.58	8.55**	8.88**
X1X2	1.3	1.44	0.19	1.26
X_1^2	-9.24	2.11	16.5***	14.74***
X_2^2	-4.13	0.83	3.29	4.6**
R^2	--	--	0.83	0.83
R^2_{adj}			0.70	0.71
CV (%)			8.41	8.51

, * significant at 5% and 1% respectively.

From table 2, the linear term of oil concentration, drying time and the quadratic term of oil concentration are significant ($p \leq 0.05$) affecting the hulling efficiency (H.E) of green gram (Table 2). Figure shows that with the increase in oil concentration and drying time, milling efficiency gradually increased up to 89.42 % and then gradually decreased. The reason may be the effect of high oil concentration which resulted in decrease of frictional rersistance of the sample inside emery roller

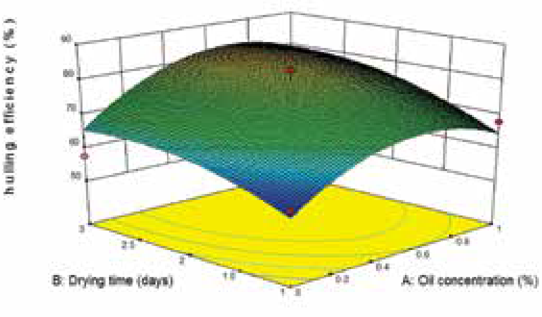

Fig 1. Effect of drying time and oil concentration on hulling efficiency

causing lower hulling efficiency. It is also noted that the asymptotic behaviour of dehulling efficiency with increasing dehulling time beyond 2.47 days was because of more broken and powder formation. Low value of R^2 suggests that the dehulling loss is also affected by other

The second-order polynomial equation for pigeon pea pulse recovery is shown in Eq. 6 as follows

H.E = 79.63+5.72*oil+6.21drying time+1.30 oil*drying

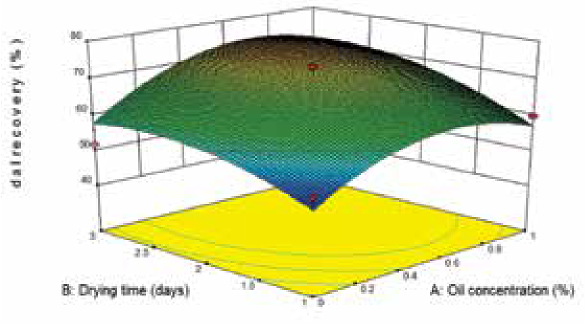

Fig 2. Effect of drying time on oil concentration on dal recovery

Dal recovery

It was observed from ANOVA (Table 2) that both linear terms and quadratic terms are significant ($p<0.05$, $p<0.001$) suggesting oil concentration and drying are more significant for dal recovery than hulling efficiency.

Dal recovery gradually increased from 51.77 % to

drying time and then gradually decreased. The reason may be the effect of high drying time which make the sample more brittle causing formation more broken and powder.

The second-order polynomial equation for pigeon pea pulse recovery is shown in Eq. 6 as follows

D.R = 71.15+5.33*oil+5.70 drying time+1.44 oil*drying time-7.88 oil2-4.40drying time2

Again, optimization of process parameters for milling of green gram was carried out to characterise hulling efficiency and dal recovery (Table 3). As per requirement, importance were given to each dependent and independent parameters.

Table 3. optimization of factors (oil concentration and drying time)

Factors/ responses	Goal	Lower limit	Upper limit	Importance
Oil concentration	In the range	0	1	3
Drying time	In the range	1	3	3
Broken	In the range	4.3	10.2	3
Powder	In the range	6.7	12.7	4
Hulling efficiency	Maximize	58.97	83.48	5
Dal recovery	Maximize	52.47	72.81	5

Table 4 Solution for optimum conditions

Solution no.	Oil percent-age	Drying time	Broken	Powder	H.E	D.R	Desirability
1	0.684	2.407	6.733	7.837	82.518	73.85	**0.766**
2	0.683	2.395	6.724	7.827	82.481	73.82	**0.746**

From Table 4 the result indicated that for the optimum condition, 0.68 % of oil concentration and 2.47 days of drying helps in recovering higher hulling efficiency as well as dal recovery. The milling experiment results were in close agreement with the dal recovery and milling efficiency values at optimized independent parameters. The findings of the optimization study, viz., the dal recovery and milling efficiency of green gram, and developed models were compared with the work carried out by Hunter (1959), Sahay and Bisht (1988), Rastogi *et al*., (1998), Mangaraj *et al*., (2004), Pratape *et al*., (2004), Zhang *et al*., (2007) and Goyal *et al*., (2008) and were found to be comparable. The dal recovery and milling efficiency of pigeon pea were obtained as 74–76% and

79– 81% at 9–10 moisture content (% db) using CIAE methods of pretreatments and 32 grades of rollers (Sahay and Bisht, 1988; Mangaraj *et al.*, 2004). Pratape *et al.*, (2004) designed and developed a mini dal mill at Central Food Technological Research Institute, Mysore (India) with a dal recovery of 75–77 % as compared to 55–60 % dal recovery for traditional chakki and 75–78 % for commercials dal mills. In the Island climate, the dal recovery was less owing to crack formations owing to sun dried samples.

Conclusions

Dehusking of green gram is one of the major problems in the processing as seed coat is tightly bound with that of cotyledons with gums and mucilages. Oil application helped in easy removal of husk and excess concentration of oil added to the extra cost and change in color of dehusked grains. The result indicated that for the optimum condition, 0.68 % of oil concentration and 2.47 days of drying helps in recovering higher hulling efficiency as well as dal recovery. The reason for low hulling efficiency may be the effect of high drying time which make the sample more brittle causing formation more broken and powder. The reason may be the effect of high drying time which make the sample more brittle causing formation more broken and powder. The broken and podwer losses varied from 4.3-10.2 % and 6.7-12.7 %

and powder were found during the experiomentation. The calculated F-value for lack of fit, for pulse recovery and milling efficiency of three pulses, were found to be less than tabular values which indicate that the regression equation obtained through RSM are in close agreement with the experimental values. Further studies are needed to examine the effect of varied moisture content, effect of different oils and use of mechanical dryer for getting higher hulling efficiency and dal recovery.

References

AOAC (2000). In: Official Methods of Analysis of the Association of Official Analytical Chemists (Horwitz W, ed), 17th edn. AOAC International, Maryland, USA

Berrios, J. D. J., Swanson, B. G., & Cheong, W. A. (1999). Physico-chemical characterization of stored black beans (Phaseolus vulgaris L.). *Food Research International*, 32(10), 669–676.

Chacko, J., Saxena, R.P., Kumbhar, B.K. & Agrawal, U.S. (2001). Pigeon pea milling: A status report. National seminar on emerging trends in processing, handling, storage and by-product utilization of pulses and soybean. GBPUAT, Pantngar.

Ehiwe, A. O. F., & Reichert, R. D. (1986). Variability in dehulling quality of cowpea, pigeon pea, and mung bean cultivars determined with the tangential abrasive dehulling device. *Cereal Chemistry*, 64(2), 86–90.

Erskine, W., Williams, P. C., & Nakkoul, H. (1991). Splitting and dehulling lentil (Lens culinaris): Effects of seed size and different pre-treatment. *Journal of Agricultural Science*, 57, 77–84.

Goyal, R. K., Vishwakarma, R. K., & Wanjari, O. D. (2008). Optimization of pigeon pea dehulling process. *Biosystems Engineering*, 99(1), 56–61.

Gowen, A. A., Abu-Ghannam, N., Frias, J., & Oliveira, J. (2008). Modeling dehydration and rehydration of cooked soybeans subjected to combined microwave – Hotair drying. *Innovative Food Science & Emerging Technologies*, 9, 129–137.

Hunter, J. S. (1959). Determination of optimum condition by experimental methods. *Indian Quality Control*, 15, 6–16.

Krishnamurthy, K., Girish, G. K., Ramasivan, T., Bose, S. K., Singh, K., & Singh, T. (1972). A new process for the removal of hull of red gram using sirka. *Bulletin of Grain Technology*, 10, 181

Kuprits, Y. N. (1967). Technology of grain processing and provender milling. Jerusalem: Israel program for scientific translation.

Kurien, P P. (1981). Advances in milling technology of pigeon pea. In: Proceedings of the international workshop on pigeon pea.

Kulkarni, S D. (1991). Food legume processing in India. *Productivity*, 32, 247–251

Kurien, P. P., & Parpia, H. A. B. (1968). Pulse milling in India. *Journal of Food Science and Technology*, 5, 203–10.

Lee, J., Ye, L., Landen, W.O., Eitenmiller, R.R. (2000). Optimization of an extraction procedure for the quantification of vitamin E in tomato and broccoli using response surface methodology. *Journal of Food Composition and Analysis*, 13, 45–57.

Mangaraj, S., Agrawal, S., Kapur, T., & Kulkarni, S. D. (2004). Effect of pre-milling treatment and abrasive rollers on milling of pulses. *Journal of Agricultural Engineering*, 41(4), 10–5.

Mangaraj, S., and Singh, K P. (2011). Optimization of machine parameters for milling of pigeon pea using RSM. *Food and Bioprocess Technology*. 4: 762-769.

Myers, R. H. & Montgomery, D. C. (2002). Response surface methodology: process and Product optimization using designed experiments (2nd ed.). New York: John Wiley & Sons, Inc.

Narasimha, H.V., Ramakrishnaiah N., Pratape V.M. and Sasikala V.B (2004). Value addition to by-products from dhal milling industry in India. *Journal of food science and technology*, 41(5), 492–496.

Phirke, P. S., & Bhole, N. G. (2000). Pretreatment of pigeonpea grain for improvement of milling characteristics. *International Journal of Food Science and Technology*, 35, 305–313.

Pratape, V. M., Sashikala, V. B., & Narasimha, H. V. (2004). Mini dhal mill—an appropriate technology for Indian rural areas for processing of pulses. *Journal of Rural Technology*, 1(2), 87–90.

Rastogi, N. K., Rajesh, G., & Shamala, T. R. (1998). Optimization of enzymatic degradation of coconut residue. *Journal of the Science of Food and Agriculture*, 76, 129–134.

Sahay, K M., & Bisht, B. S. (1988). Development of a small abrasive cylindrical mill for milling pulses. *International Journal of Food Science and Technology* 23, 17–22

Singh, U., Santosa., B, A, S., & Rao, P, V. (1992). Effect of dehulling methods and physical characteristics of grains on dhal yield of pigeon pea (*Cajanus cajan*) genotypes. *Journal of Food Science & Technology*, 29, 350–353.

Tiwari ,B. K, Jaganmohan, R. & Vasan, B. S. (2005). Effect of heat processing on milling of black gram and its end product quality. Journal of Food Engineering, 78, 355-360.

Weng, W., Liu, W. & Lin, W. (2001) Studies on the optimum models of the dairy product Kou Woan Lao using response surface methodology. *Asian–Australasian Journal of Animal Sciences*, **14** (10), 1470–1476.