Application of Factorial Design to Study the Effect of Moisture and Rice of Varieties on the Production of Paddy Husker Machine

S. Phanphet, N. Sukprasert, A. Wangmai, S. Bangphan, and P. Bangphan

Member, IAENG

***Abstract*— Production of paddy husker machine was investigated. Three and four level Full Factorial Design has been employed to study the effect of different experimental variables on the production of paddy husker machine. Two variables of moisture (10, 12, 14 and 16 of percentage), rice of varieties (khao dawk mail 105, RD6 and riceberry) were used to identify the significant effects and interactions in the batch studies. A polynomial regression model has been developed using the experimental data. The results show that production of paddy husker was strongly affected by the variations in rice of varieties. The maximum paddy husker activity was achieved when the production was carried out at 12 of moisture, with khao dawk mali 105 of paddy husker. The predicted value produced 89.0 of good percentage is in close agreement with paddy husker activity produce from experiment, which is 88.8 of good percentage.**

***Keywords*-Effect, moisture, rice of varieties, paddy husker, full factorial design.**

I. INTRODUCTION

THE quality of peeled rice are depends on many factors such as rice strain, the rate of feeding, clearance between a rubber to rubber cylinder and paddy moisture content which usually are controlled not to be exceed 14%. But the most important factor is the type of the abrasives [1]-[2].

S. Phanphet, Act. SubLt. Ph.D, lecturer Department of Industrial Technology Faculty of Science and Technology Chiang Mai Rajabhat University 202 Chang Puak road, Tambon Chang Puak, Maung District, Chiang Mai, Thailand, 50300 +66 53 88 5600 , (+66)8 6354 5445 (E-mail : suwattwong@gmail.com).

N. Sukprasert lecturer Department of Industrial Technology Faculty of Science and Technology Chiang Mai Rajabhat University 202 Chang Puak road, Tambon Chang Puak, Maung District, Chiang Mai, Thailand, 50300 (+66) 53 88 5600 , (E-mail: narongsuk269@gmail.com).

A. Wangmai lecturer Department of Industrial Technology Faculty of Science and Technology Chiang Mai Rajabhat University 202 Chang Puak road, Tambon Chang Puak, Maung District, Chiang Mai, Thailand, 50300 +66 53 88 5600 , (+66)8 6354 5445).

S. Bangphan Asst. Prof. Ph.D. Department of Industrial Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna. 128 Huay kaew Road, Muang District, Chiang Mai, Thailand, 50300; (corresponding author to provide phone: (+66) 5392-1444; fax : (+66)5321-3183 ; e-mail : pong_pang49@yahoo.com).

P. Bangphan Asst. Prof. Department of Industrial Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna. 128 Huay kaew Road, Muang District, Chiang Mai, Thailand, 50300, (+66) 5392-1444; fax: (+66)5321-3183 ;e-mail : foundry18@yahoo.com).

Rice supply is another advantage of brown rice relative to polished or white rice. Post harvest researchers say that the milling recovery in brown rice is 10% higher than polished rice [4]. There is the other benefit of brown rice – economics the fuel savings in milling is 50-60% because the polishing and whitening steps are eliminated. It follows that the milling time is also shortened; labor is less; and the cost of equipment (if the mill is dedicated to brown rice) is much lower because the miller doesn't have to install polishers and whiteners. The enhancement in output volume and the economy in milling constitute the business opportunity in brown rice. [5].

Brown Rice

White Rice

Fig. 1. Brown Rice versus White Rice [6]

A. Literature Review

Milling is the primary difference between brown and white rice. The varieties may be identical, but it is in the milling process where brown rice becomes white rice. Milling, often called "whitening", removes the outer bran layer of the rice grain. Milling affects the nutritional quality of the rice. Milling strips off the bran layer, leaving a core comprised of mostly carbohydrates. In this bran layer resides nutrients of vital importance in the diet, making white rice a poor competitor in the nutrition game. The following chart shows the nutritional differences between brown and white rices. Fiber is dramatically lower in white rice, as are the oils, most of the B vitamins and important minerals. Unknown to many, the bran layer contains very important nutrient such as thiamine, an important component in mother's milk [7]. Brown rice (hulled rice) is composed of surface bran (6–7% by weight), endosperm (E90%) and embryo (2–3%) [8] White rice is referred to as milled, polished or whitened rice when 8–10% of mass (mainly bran) has been removed from brown rice [8]. During milling, brown rice is subjected to abrasive or friction pressure to remove bran layers resulting in high, medium or low degrees of milling depending on the amount

ISBN: 978-988-14048-9-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

of bran removed [8],[10].Milling brings about considerable loss of nutrients and affects the edible properties of milled rice[8],[10]. As most cereals, rice does not show a homogeneous structure from its outer (surface) to inner (central) [11]. As a consequence, information on the distribution of nutrients will greatly help in understanding the effect of milling and aid in improving sensory properties of rice while retaining its essential nutrients as much as possible [12].Therefore, the aim of this study is to generate between rice of varieties and rice of moisture using Design of Experiment(DOE) by full factorial design in order to generate the suitable factors.

This study is going to follow the framework set with some modifications to brown rice peels, so that we can investigate the possibility of using full factorial design to improve our complete of good percent rice results by only varying the period of time. Besides, the study focus on the effect of varying selection rice of varieties and rice of moisture respectively.

II. Experimental Procedure

A. *Material and Method*

The most outer rough shell of paddy is removed. Rubber roll sheller (Fig. 2) is the most common machine that is used for paddy shelling, however friction type browner is sometimes used as a sheller. Paddy goes between three rubber rollers that are rotating in opposite direction with different velocities. There is a small clearance between the rollers so that when paddy passes through, it is subjected to some shear forces and husk is removed from production process of rice milled.

B. Method

Design of experiments (DOE) and full factorial design is a collection of statistical and mathematical techniques useful for developing, improving and optimizing process and new products, as well as the improvement of existing product designs. Full factorial design can take unknown response function and approximate it by coded variables where these coded variables are usually defined to be dimensionless with zero mean and the same spread or standard deviation. Usually a low order polynomial in some relatively small region of the independent variable space is generated. The approach presented in this paper is a statistically based method which combines design of experiments (DOE) and full factorial design [13]. The inability to perform the trials of a factorial experiment in a completely random order is often due to imposed randomization restrictions on the experiment trials. In recent years, considerable attention has been devoted to factorial and fractional factorial layouts with restricted randomization, such as blocked designs [14-17] split-plot designs [18-26]. Although the treatment structure of these designs are identical, they dier in the randomization structures. These designs are often larger than the completely randomized designs. The following is a brief review of some common designs.

In order to maximize the paddy husker production, Full Factorial Design for two independent variables was adopted. The Experimental Design was based on Minitab Release 15.00 Full Factorial Design was used to obtain the combination of values that can optimize the response within the region of the two dimensional observation spaces, which allows one to design a minimal number of experimental runs[36]. The variables were rice of moisture, and rice of varieties, were submitted for the analysis in the design. The variable of each constituent at levels –1, 0 and+1 is given in Table 1. The selection of low, middle and high levels for all these variables were based on a prior screening done in our workshop. A $4x3^2$ full factorial design at the center point, leading the total number of 36 experiments. The behavior of the present system described by the following equation (1), which includes all interaction terms regardless of their significance:

$$\hat{y}_k = \beta_0 + \beta_1\, x_1 + \beta_2\, x_2 + \beta_{12}\ \ x_1 x_2 + \beta_{21} x_2\ x_1 \qquad (1)$$

Where β are the coefficients which have calculated using an appropriate method such as the least square method. When the result estimated surface is an adequate approximation of the true response function, the results will be approximately equivalent to analysis of the actual system. The model parameters can be approximated whenever proper experimental designs are used to collect the data. The DOE simulation was accomplished with two parameters : between rice of moisture and rice of varieties respectively. It was performed according (see Table II and III), and Diagram of paddy husker production process on modeling in Fig. 2.

TABLE I
DOE PARAMETERS

Parameter	Variable	Code level -1	0	1
Rice of Moisture , RM	X_1 (percent)	10	12,14	16
Rice of Varieties, RV	X_2 (type)	1	2	3

A model fitting was accomplished for the first 3^2-full factorial design in Table III.

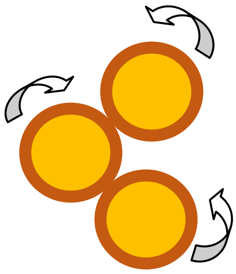

Fig.2. Diagram of paddy husker process

III. Implementation and Results

A. DOE and full factorial design. The DOE simulation was accomplished with two parameters: rice of moisture (RM),) and rice of varieties (RV) respectively. It was performed according (see Table II and III), and paddy husker production in Fig 2. A model fitting was accomplished for the first 3^2-full factorial design in Table III. The independent (RM with RV) and the dependent variables were fitted to the second-order model equation and examined in terms of the goodness of fit. The analysis of variance (ANOVA) was used to evaluate the adequacy of the fitted model. The R-square value (determination coefficient) provided a measure of how much of the variability in the observed response values could be explained by the experiment factors and their interactions.

DOE order defines the sequence that variables should be introduced in response surface analysis. See Table III shows the results according to simulated analysis performed in MINITAB Release 15.00 used for simultaneous optimization of the multiple responses. The desired goals for each variable and response were chosen. All the independent variables were kept within range while the responses were either maximized. The significant terms in different models were found by analysis of variance (ANOVA) for each response. Significance was judged by determining the probability level that the F-statistic calculated from the data is less than 5%. The model adequacies were checked by R^2, adjusted-R^2 (adj-R^2).The coefficient of determination, R^2, is defined as the ratio of the explained variation to the total variation according to its magnitude. It is also the proportion of the variation in the response variable attributed to the model and was suggested that for a good fitting model, R^2 should not be more than 99.86 %. A good model should have a large R^2, adj-R^2. Response surface plots were generated with MINITAB Release 15.00.

Regression Equation equations were obtained from design of experiments. Using all values (tests 1 to 36) to the system analysis, the following polynomial equations were generated.

The Estimated Regression Coefficients for percentage of good rice using data in uncoded units:

Yields = 75.3234 - 5.178 Moisture_1 + 8.677 Moisture_2
+ 2.713 Moisture_3 - 6.212 Moisture_4
+ 9.036 Rice Varieties_1 - 0.963 Rice Varieties_2 -
8.073 Rice Varieties_3
+ 3.256 Moisture*Rice Varieties_1 1 -
1.183 Moisture*Rice Varieties_1 2
- 2.072 Moisture*Rice Varieties_1 3 -
4.036 Moisture*Rice Varieties_2 1
- 6.037 Moisture*Rice Varieties_2 2
+ 10.073 Moisture*Rice Varieties_2 3
- 0.073 Moisture*Rice Varieties_3 1
+ 5.036 Moisture*Rice Varieties_3 2
- 4.963 Moisture*Rice Varieties_3 3
+ 0.853 Moisture*Rice Varieties_4 1
+ 2.185 Moisture*Rice Varieties_4 2 -
3.038 Moisture*Rice Varieties_4
(2)

Regression Equation (2) is generate the graphic shown in Fig. 3 shows optimal solutions considering rice of moisture , and rice of varieties respectively. Main solutions are positioned at 1,2 and 3 type (khao dawk mail 105, RD6 and riceberry) , and there is a range between 10.00 and 16.00 percent of rice moisture where it is allowable to use other distances (see TableI. DOE parameter). Result of the analysis of variance is given in Table III.

TABLE II
EXPERIMENTAL DESIGN

Run	StdOrder	RunOrder	PtType	Blocks	Moisture	Varieties	Yield
1	23	1	1	1	4	2	69.000
2	36	2	1	1	4	3	58.000
3	11	3	1	1	4	2	71.000
4	4	4	1	1	2	1	89.000
5	16	5	1	1	2	1	89.000
6	12	6	1	1	4	3	58.000
7	20	7	1	1	3	2	81.000
8	5	8	1	1	2	2	77.000
9	8	9	1	1	3	2	83.000
10	19	10	1	1	3	1	87.000
11	26	11	1	1	1	2	68.000
12	6	12	1	1	2	3	86.000
13	29	13	1	1	2	2	77.000
14	7	14	1	1	3	1	87.000
15	32	15	1	1	3	2	82.330
16	33	16	1	1	3	3	65.000
17	13	17	1	1	1	1	83.000
18	18	18	1	1	2	3	86.000
19	30	19	1	1	2	3	86.000
20	27	20	1	1	1	3	60.000
21	21	21	1	1	3	3	65.000
22	34	22	1	1	4	1	79.000
23	10	23	1	1	4	1	79.000
24	24	24	1	1	4	3	58.000
25	17	25	1	1	2	2	77.000
26	1	26	1	1	1	1	82.313
27	9	27	1	1	3	3	65.000
28	22	28	1	1	4	1	79.000
29	2	29	1	1	1	2	68.000
30	31	30	1	1	3	1	87.000
31	35	31	1	1	4	2	71.000
32	28	32	1	1	2	1	89.000
33	3	33	1	1	1	3	60.000
34	14	34	1	1	1	2	68.000
35	15	35	1	1	1	3	60.000
36	25	36	1	1	1	1	82.000

ISBN: 978-988-14048-9-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

TABLE III
ANALYSIS OF VARIANCE FOR THE EXPERIMENTAL RESULTS OF THE FULL FACTORIAL DESIGN

Source	DF	SS	MS	F	P
Model	11	3811.18	346.471	1580.08	0.000
Linear	5	3105.47	621.094	2832.50	0.000
Moisture	3	1332.40	444.133	2025.47	0.000
Rice Varieties	2	1773.07	886.536	4043.05	0.000
2-Way Interactions	6	705.71	117.618	536.40	0.000
Moisture *Rice Varieties	6	705.71	117.618	536.40	0.000
Error	24	5.26	0.219		
Total	35	3816.44			

TABLE IV
ESTIMATED REGRESSION COEFFICIENTS FOR YIELDS

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	75.3234	0.0780	965.13	0.000	
Moisture					
1	-5.178	0.135	-38.30	0.000	1.50
2	8.677	0.135	64.19	0.000	1.50
3	2.713	0.135	20.07	0.000	1.50
Rice Varieties					
1	9.036	0.110	81.87	0.000	1.33
2	-0.963	0.110	-8.72	0.000	1.33
Moisture*Rice Varieties					
1 1	3.256	0.191	17.03	0.000	2.00
1 2	-1.183	0.191	-6.19	0.000	2.00
2 1	-4.036	0.191	-21.11	0.000	2.00
2 2	-6.037	0.191	-31.58	0.000	2.00
3 1	-0.073	0.191	-0.38	0.707	2.00
3 2	5.036	0.191	26.34	0.000	2.00

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.468267	99.86%	99.80%	99.69%

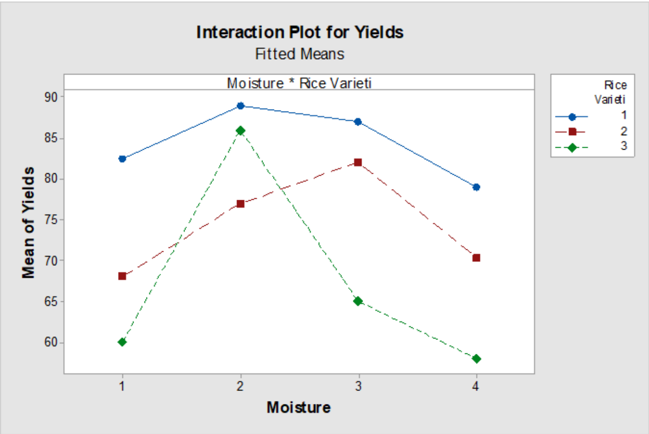

Fig.3. interaction plot for Yields

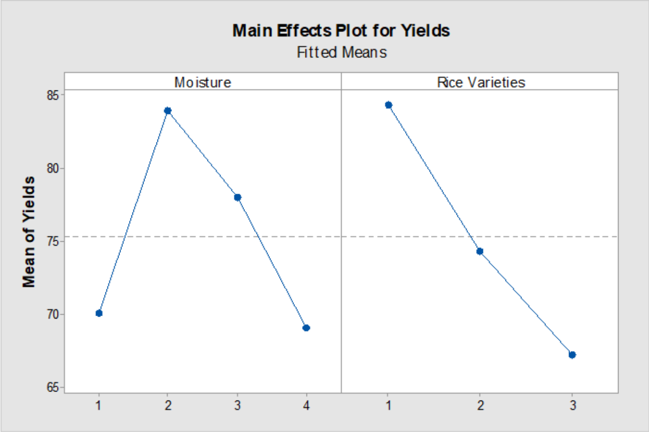

Fig.4. Main effects plot for Yields

There is no significant evidence of lack of fit at a = 0.05. Therefore, this study can conclude that the true response surface is explained by the linear model. To study the effects of three factors, 3^2 = 36 runs are required. Due to space limitations, the treatments, factor values, and the corresponding responses are not shown. Analysis of variance method (ANOVA) is used to find factors with significant effects. EffectsX_1,X_2,X_1X_1,X_2X_2, ,X_1X_2 $X_2X_1$and DF are found to be significant ,that is the most significant effect, has significant interactions with all other factors. Alternatively, these results can be obtained visually from the residual versus fits probability plot of effects method shown in Fig.3 plot the range of the residuals looks essentially constant across the levels of the predictor variable, rice of varieties and rice of moisture. The scatter in the residuals at RV between 1 and 2 type and rice of moisture between 10.00 to 16.00 percent that the standard deviation of the random errors is the same for the responses observed at each rice of varieties and rice of moisture.

Result of Estimated regression coefficients for the response (percentage of good rice) function as surface paddy husker is presented in Table V. This analysis is carried out for a significance level of 5%, i.e., for a confidence level of 95%. The model adequacies was checked by adjusted-R^2 (adj-R^2) of 99.69%.

The check of the normality assumptions of the data is then conducted, it can be seen in Fig. 4 that all the points on the main effect plot come close to forming a straight line. This implies that the data are fairly normal and there is no deviation from the normality. The response taken from Table IV revealed that the square coefficients of RV (X_1) and RM(X_2), have a remarkable effect on the percentage of good rice yield. Moreover, all the linear and interaction terms of three factor presented in significant effects on the percentage of good rice yield at 5% probability level.

ISBN: 978-988-14048-9-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

IV. CONCLUSION

The results of this study have clearly indicated full factorial design is an effective method for optimization of good rice. Response surface methodology was successfully applied to optimize rice of varieties and rice of moisture in brown rice that was not paddy. When productions into the formulation, the optimized levels of R-Squire $_{(adjust)}$ was 96.67 % and standard deviation was 0.468267 yielded good quality peeling. This study clearly showed that full factorial design was one of the suitable methods to optimize the best operating conditions to maximize the mill removing. Graphical response surface and contour plot were used to locate the optimum point. The statistical fitted models and the contour plot of responses, can be used to predict values of responses at any point inside the experimental space and can be successfully used to optimize the brown rice peeling machine. Also, the size and amount of this surface degradation was noticeably increased as a function of exposure time. The surface methodology was used. The optimal composition of the paddy husker established by a full factorial design (run order 36) was: rice of varieties (khao dawk mail 105) and rice of moisture 12.00 percent. The optimal values for the brown rice peeling parameters were good rice of 99.67 %.

ACKNOWLEDGMENT

Financial support department of Industrial education, RMUTL: Rajamangala University of Technology Lanna, Chiang Mai and Chiang Mai Rajabhat University is gratefully acknowledged.

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