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Optimization of Factorial Design with the type of Plackett-Burman Design to Study the Effects of Organic Rice Production Process: First Step Experiment

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ABSTRACT
The research aims at the optimization to determine factors production process of the of the output organic rice so that the best possible set of parameters affecting it can be selected to get the desired output. For this purpose, the effect of various parameters on the organic rice output is studied. To facilitate the study and detailed analysis, a statistical model is constructed which is used to predict and optimize the performance of the system. Efficient organic rice optimization determines the input variable settings to adjust the organic rice of the organic rice according to the consumption of the parts in the next phase of production process. To study the interaction among the factors a 36 factorial experiment approach has been adopted using the two basic principles of experimental design replication and randomization. The process model was formulated based on analysis of variance (ANOVA) and regression of coefficient using Minitab Release 19.00. The output is represented graphically and in the form of empirical model which defines the performance characteristics of the production process of organic rice by factorial design type of Placket-Burman design.

Key words: Factorial design, Plackett-Burman ANOVA, regression of coefficient, optimization, production process, organic rice

1. INTRODUCTION

The quality of peeled rice is depending 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% [1], [2]. In rice milling, the bran layers and germ removed during polishing are high in fiber, vitamins and minerals as well as protein. Their removal results in loss of nutrients, especially in substantial losses of B vitamins. Polishing rice reduces the thiamin content of rice by over 80%. Parboiled rice is therefore higher in B vitamins than raw milled rice [3].

The enhancement of 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 [5].

Milling strips off the bran layer, leaving a core comprised of mostly carbohydrates [6]. 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 rice. Fiber is dramatically lower in white rice, as are the oils, most of the B vitamins and important minerals [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 [7]. 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 of bran removed [7]-[10]. Milling brings about considerable loss of nutrients and affects the edible properties of milled rice [7]-[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 purpose of this research is to generate between clearance of rubber and spindle of speed of rice using Design of Experiment (DOE) by factorial design with type of plackett-burman design in order to generate the suitable factors. For some parameter optimization on organic rice.

2. EXPERIMENTAL DESIGN

2.1. Factorial Design of Experiments

Optimum conditions are decided by changing several factors at once and using different levels of these factors. Factorial designs are widely applied in the experiments that are taking into account several factors where it is necessary to study the interaction effect of factors on the response [13]. 2^k factorial design of experiments needs a smaller number of experiments for several factors; thus, materials and time used are slightly reduced [14],15]. When factorial design methods applied to experiments of a process, mathematical models are derived through obtained variance analysis tables. Experiments are chosen randomly to prevent partiality of researchers [16].

The factorial design with type of design Placket-Burman design describes which factor shows more impact and influences the variation of one factor on the other factors [17]. The two factors; spindle of speed (SS) and the rubber of clearance (CL), respectively were varied at two levels as given in (see Table 1) to investigate their effects on response.

Table 1: Factors and levels for organic rice production experiment

Parameter	Variable	Lower Limit	Upper Limit
Spindle of speed, SS	X_1 (RPM)	1,420	1,460
Rubber of clearance, CL	X_2 (mm.)	1.0	1.2

Table 2: Design matrix for DOE 2^k factorials

Run Order	Pt Type	Blocks	X_1	X_2	RESPONSE
1	1	1	1	-1	75.360
2	1	1	1	-1	75.300
3	1	1	-1	-1	88.410
4	1	1	1	-1	75.330
5	1	1	-1	1	81.040
6	1	1	-1	-1	87.210
7	1	1	-1	1	82.115
8	1	1	1	1	70.220
9	1	1	1	-1	76.420
10	1	1	1	1	70.180
11	1	1	-1	1	80.020
12	1	1	-1	-1	88.400
13	1	1	1	1	70.420
14	1	1	-1	1	80.936
15	1	1	-1	-1	89.210
16	1	1	-1	-1	90.100
17	1	1	-1	1	79.910
18	1	1	1	-1	75.490
19	1	1	-1	-1	90.210
20	1	1	1	1	70.380
21	1	1	-1	-1	89.990
22	1	1	1	-1	79.410
23	1	1	-1	1	79.380
24	1	1	1	1	70.420
25	1	1	1	1	70.810
26	1	1	1	-1	78.990
27	1	1	-1	1	80.020
28	1	1	-1	-1	86.450
29	1	1	-1	1	79.490

Table 2: (Cont.) Design matrix for DOE 2k factorials

Run Order	Pt Type	Blocks	X1	X2	RESPONSE
30	1	1	-1	1	82.115
31	1	1	1	1	70.090
32	1	1	1	1	70.810
33	1	1	1	-1	75.210
34	1	1	1	1	70.410
35	1	1	1	-1	75.380
36	1	1	-1	-1	90.280

The 2^k = 36 factorial with three replicated treatment combinations were performed. Note that 36 samples were made at the coded treatment combination (0, 0). The observed percentage of good rice ranged from 70.090 to 90.280 %. Table 2 presents the results for all 2^k = 36 runs, run order by response. Therefore, thirty- six observations were taken in all to employ factorial design type of Plackett-Burman design as shown in (see Table 2).

Throughout the experiment it was assumed that: the factor is fixed; the design was completely randomized and the usual normality assumptions of the data were satisfied.

2.2 Statistical Methods and Software

The analysis and results of the experimental design were studied and interpreted by MINITAB RELEASE 19.00 (PA, USA licensed to Department of Industrial Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna, Chiang Mai, Thailand) statistical software to estimate the response of the dependent variable. The response curves and contour plots are also generated. After production process of organic rice, the response was calculated and analyzed using regression coefficient analysis and analysis of variance (ANOVA).

2.3 Hypothesis

Definition of Statistical hypothesis
Statistical hypothesis that are evaluated by appropriate statistical techniques.
There are two hypotheses involved in hypothesis testing

- Null hypothesis H_0: $\mu_1 = \mu_2$ (there is not significantly different in mean the percentage of good rice).
- Alternative hypothesis H_1: $\mu_1 \neq \mu_2$ (at least one different in mean the percentage of good rice).

The level of significance (α) is a probability and, in fact, is a probability of rejecting a true null hypothesis.

The level of significance (α) are as follows:
If the p-value < α, then reject H0 that means there are at least one level significantly different.

If the p-value ≥ α, then failed to reject H_0 that means no significantly different.

3. RESULTS AND DISCUSSION

3.1 Results

The DOE simulation was accomplished with two parameters: spindle of speed and rubber of clearance respectively. It was performed according (see Table 1 and 2), and of main effects for the response as shown in Figure 1. A model fitting was accomplished for the first 2^k factorial design with type of Plackett-Burman design (see Table 1). The independent (SS and CL) 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. (see Table 1) shows the results according to simulated analysis performed in MINITAB Release 19.00 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 or minimized. 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 75 %. The calculated value is greater than the value in the table and therefore accepts the results that are significantly different at the confidence level (p-value < α, 0.005 < 0.05), (SS x CL) for source model and two-way interactions. A good model should have a large R^2, adj-R^2. Response surface plots were generated with MINITAB Release 19.00. The results of the above experiments then conducted analysis of variances (ANOVA) to determine the influence of factors on the response (see Table 3).

Table 3: Analysis of variance (95 % confidence)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	1634.8	544.95	368.00	0.000
Linear	2	1621.2	810.65	547.42	0.000
SS	1	1163.4	1163.4	785.66	0.000
CL	1	457.85	457.85	309.18	0.000
2-Way Interactions	1	13.55	13.55	9.15	0.005
SS*CL	1	13.55	13.55	9.15	0.005
Error	32	47.39	1.48		
Total	35	1682			
Model summary		S	R-sq	R-sq(adj)	R-sq (pred)
		1.2169	97.18 %	96.92%	96.4 %

3.2. Hypothesis Testing

An alternative decision rule using the p - value definition. The p-value is defined as the smallest value of α for which the null hypothesis can be rejected.

If the p-value is less than or equal to α, we reject the null hypothesis (p < α).

If the p-value is greater than α, we do not reject the null hypothesis (p ≥ α).

3.3.1 Spindle of Speed Factor

For the response, the value of p was 0.000. Thus, the conclusion is rejecting H_0, which means there are significant differences between the levels in the *p*. The response is shows that the response significant effect on production process of organic rice.

3.3.2 Clearance Factor

For the response, the value of *p* was 0.000. Thus, the conclusion is rejecting H_0, which means there are significant differences between the levels in the *p*. The response is shows that the response significant effect on production process of organic rice.

3.2.3 Spindle of Speed and Clearance (Two-Way Interaction)

For interaction with the spindle of speed and clearance the value of *p* was 0.005. So, the conclusion is rejecting H_0, which means there are significant differences between the levels spindle of speed and clearance. The differences of response between level of each factor as shown in Figure 1 and mean of response of each level (see Table 3 and Table 4).

While the remaining interaction the p ≥ α which means there is significant difference between the level of the spindle of speed and clearance interaction. This suggests that the spindle of speed, and clearance are significant effect of response in production process of organic rice.

Figure 1 shows the main effects of the two factors (X_1 and X_2) response. The effect of a factor is the change in response produced by the change in level of factor. This is frequently called a main effect as it refers to the primary factor of interest in the experiment [18]. It was concluded that the larger the vertical line is Figure 1, the larger the change in of response when it is changing from level −1 to level +1. Please note that the statistical significance of a factor is directly related to the length of the vertical line [19].

Table 4: Code coefficients 2^k design)

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		79.053	0.203	389.78	0.000	
SS	-11.370	-5.685	0.203	-28.03	0.000	1.00
CL	-7.132	-3.566	0.203	-17.58	0.000	1.00
SS*CL	1.227	0.613	0.203	3.02	0.005	1.00

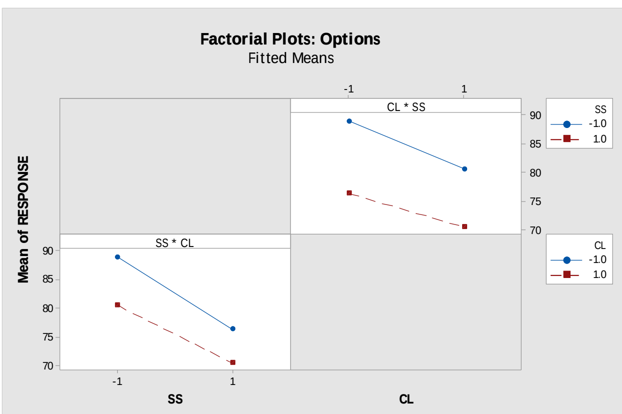

Figure 1: Plots of main effects for the response.

Analysis of variance is a statistical method that partitions the total variation into its component parts each of which is associated with a different source of variation [17]. The interaction effects are easily estimated and tested by using the usual ANOVA. The ANOVA results of the response were shown in (see Table 2). The sum of the squares used to estimate factors affect and Fisher's F ratios (defined as the ratio of mean square effect and the mean square error) and p values (defined as the level of significance leading to the rejection of the null hypothesis) were also represented.
The individual and interaction effects was given by the pareto chart of the standardized effects in as shown in Figure 2. In order to identify whether the calculated effects were significantly different from zero, Student's t-test was performed and horizontal columns in Pareto chart showed these values for each effect. For a 95% confidence level and seven degrees of freedom t value was equal to 2.04. The minimum statistically significant effect magnitude for 95% confidence level is represented by the vertical line in the chart. Four values higher than 2.04 (P = 0.05) were located at right of the dash line and were significant.

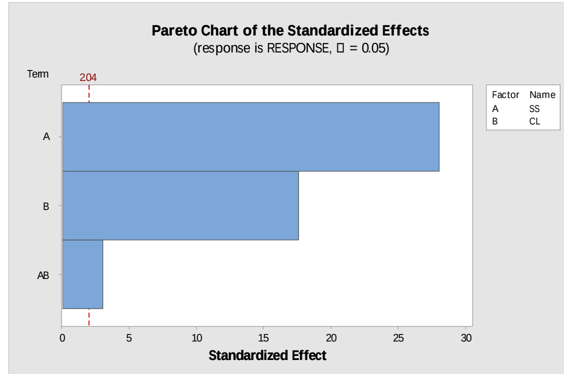

Figure 2: Pareto chart of standardized effects on the response

4 CONCLUSIONS

A factorial experiment design type of Plackett-Burman design has been developed which can be used for the optimization of output organic rice of the production process of the organic rice. Such a model not only assists to estimate the magnitude and direction of the effects of change in factors but also predicts the effects of their mutual interactions.

The experimental results show that the spindle of speed and clearance factor did not have a significant effect on the response. The spindle of speed and clearance has a significant impact on the response. The optimal level of spindle of speed and clearance are 1,420 rpm and 1.00 millimeters respectively. Production process of organic rice at this level will meet the requirement of Community enterprises. The response with the two-level selected of organic rice can be modeled using the factorial design with type of Plackett-Burman design, as well as the response surface regression method. The value of R^2 (86.85 %) and R^2 adj (85.61%) of the obtained models show that the models fit all the cases.

The significant effect of independent factors was analyzed using ANOVA, and the effect was also reported in the form of maim effects plots. The design of experiments provides efficient tools for the optimization of variable factors for general by factorial design type of Plackett-Burman design.

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