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Implementation of Response Surface Methodology using in Small Brown Rice Peeling Machine: Part I

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Abstract**—**Implementation of response surface methodology (RSM) was employed to study the effects of two factor (rubber clearance and round per minute) in brown rice peeling machine of The optimal BROKENS yield (19.02, average of three repeats),.The optimized composition derived from RSM regression was analyzed using Regression analysis and Analysis of Variance (ANOVA). At a significant level α = 0.05, the values of Regression coefficient, $R^2_{(adj)}$ were 97.35 % and standard deviation were 1.09513. The independent variables are initial rubber clearance, and round per minute parameters namely. The investigating responses are final rubber clearance, and round per minute (RPM). The restriction of the optimization is the designated.

Keywords**—**Brown rice, Response surface methodology(RSM), Rubber clearance, Round per minute (RPM), Peeling machine.

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, paddy moisture content which usually are controlled not to be exceed 14% ect. But the most important factor is the type of the abrasives [1]-[2]. Nutritional Implications of Rice Milling: 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%. Parboiling results in gelatinization of the starch and disintegration of the protein in the endosperm resulting in inward shift of water-soluble vitamins to the endosperm. Parboiled rice is therefore higher in B vitamins than raw milled rice [3] and see Table 1. Brown Rice Is Superior to Polished Rice: Brown rice has high dietary fiber (a gentle laxative, prevents gastro-intestinal diseases and good for diabetes sufferers); rich in B vitamins and minerals (prevents beriberi); and high in fat (energy source). Also it has been reported that brown rice contains high phytic acid (antioxidant, anti-cancer); it decreases serum cholesterol (prevents cardio-vascular diseases); and it is considered a low glycemic index food (low starch, high complex carbohydrates which decreases risk to type 2 diabetes). 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. The enhancement in output volume and the economy in milling constitute the business opportunity in brown rice. [5].

TABLE I
NUTRIENT CONTENT OF RICE [3]

mg/10g	Brown rice	Polished rice
Thiamine	0.34	0.07
Riboflavin	0.05	0.03
Niacin	4.7	1.6
Iron	1.9	0.5
Magnesium	187.0	13.0

Brown Rice White Rice

Fig. 1 Brown Rice versus White Rice

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 [6]. Brown rice (hulled rice) is composed of surface bran (6–7% by weight), endosperm (E90%) and embryo (2–3%) [7] White rice is

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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 of bran removed [7,9].Milling brings about considerable loss of nutrients and affects the edible properties of milled rice[7,9]. As most cereals, rice does not show a homogeneous structure from its outer (surface) to inner (central) [10]. 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[11].Therefore, the aim of this study is to generate between clearance of rubber with round per minute using Design of Experiment (DOE) 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 Response Surface Methodology to improve our broking results by only varying the period of time. Besides, the study focus on the effect of varying selection clearance of rubber and round per minute.

II. Experimental Procedure

A. Materials and Method

Paddy (rough rice) must be milled after harvesting and drying. In milling process uneatable hulls and bran are removed from paddy and brown rice is produced. In general,

rice peeling process consists of two main operations combination:

When paddy comes to the milling system it may contain some foreign materials such as stones, stalk, dust, soil particles, and weed seeds; therefore, it is necessary to pass the paddy though a cleaning system. This cleaning system can be a simple sieve or a progressive system.

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 two 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 it.

B. Method

Design of experiments (DOE) and Surface Response Methodology Surface Response Methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving and optimizing process and new products, as well as in the improvement of existing product designs. RSM 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 response surface methodology (RSM) [12]. RSM is generally conducted in three phases, as emphasized according to research conducted Myers and Montgomery[13].The fundamentals of RSM are set out in the semina papers of [13]-[17]. Further developments are drawn together in three key review articles, namely those of [18]-[20].The example presented above demonstrates that designs taken from the RSM paradigm can be used to good effect in a traditional agricultural setting and this point is further underscored by the work of [17],[21]. And According to Hill and Hunter, *RSM* method was introduced by G.E.P. Box and K.B. Wilson in 1951.Box and Wilson suggested to use a first-degree polynomial model to approximate the response variable. They acknowledged that this model is only an approximation, not accurate, but such a model is easy to estimate and apply, even when little is known about the process [22]. The resulting surfaces, usually linear or quadratic, are fitted to these points. Often statistical methods such as design of experiments are used to determine where in the design space these points should be located in order to obtain best possible fit. In this paper we use linear polynomials to create the response surface. The creation of such response surface models to approximate detailed computer analysis codes is particularly appropriate in the preliminary design stages when comprehensive trade-offs of multiple performance and economic objectives is critical. In many cases, either a second-order model is used. For the case of two independent variables, the second-order model is:

$$y_k = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} \beta_{ij} x_i x_j \quad (1)$$

III. Implementation and Results

A. DOE and Surface Response Methodology

The DOE simulation was accomplished with two parameters: between rubber clearance and round per minute. It was performed according (see Table II and III), and brown rice peeling machine in Fig 2. A model fitting was accomplished for the first 2^2-CCD in Table III. The independent (rubber clearance with RPM) 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.

TABLE II
DOE Parameters

Parameter	Variable	Lower Limit	Upper Limit
Rubber Clearance	x_1	1.2	1.5
Round Per Minute	x_2	1440	1500

TABLE III
DOE SET AND RESULTS

Std Order	Run Order	Pt Type	Blocks	clearance	rpm	brokens
2	1	1	1	1.65000	1440.00	25.0
3	2	1	1	1.25000	1600.00	35.0
35	3	0	1	1.45000	1520.00	20.0
30	4	1	1	1.65000	1440.00	25.8
15	5	1	1	1.25000	1440.00	25.8
4	6	1	1	1.65000	1600.00	32.1
17	7	1	1	1.25000	1600.00	35.4
31	8	1	1	1.25000	1600.00	35.1
19	9	0	1	1.45000	1520.00	20.6
32	10	1	1	1.65000	1600.00	31.8
20	11	0	1	1.45000	1520.00	19.7
29	12	1	1	1.25000	1440.00	25.5
18	13	1	1	1.65000	1600.00	32.4
21	14	0	1	1.45000	1520.00	20.5
1	15	1	1	1.25000	1440.00	25.8
6	16	0	1	1.45000	1520.00	20.5
16	17	1	1	1.65000	1440.00	25.9
5	18	0	1	1.45000	1520.00	19.8
7	19	0	1	1.45000	1520.00	19.9
34	20	0	1	1.45000	1520.00	20.1
33	21	0	1	1.45000	1520.00	20.2
40	22	0	2	1.45000	1520.00	20.4
23	23	-1	2	1.73284	1520.00	31.1
13	24	0	2	1.45000	1520.00	20.1
9	25	-1	2	1.73284	1520.00	31.8
39	26	-1	2	1.45000	1633.14	38.1
27	27	0	2	1.45000	1520.00	20.2
25	28	-1	2	1.45000	1633.14	38.4
42	29	0	2	1.45000	1520.00	20.4
10	30	-1	2	1.45000	1406.86	22.4
26	31	0	2	1.45000	1520.00	20.8
8	32	-1	2	1.16716	1520.00	35.5
28	33	0	2	1.45000	1520.00	20.2
22	34	-1	2	1.16716	1520.00	35.7
41	35	0	2	1.45000	1520.00	19.8
38	36	-1	2	1.45000	1406.86	22.4
37	37	-1	2	1.73284	1520.00	33.4
14	38	0	2	1.45000	1520.00	20.4
24	39	-1	2	1.45000	1406.86	25.5
11	40	-1	2	1.45000	1633.14	38.8
36	41	-1	2	1.16716	1520.00	35.8
12	42	0	2	1.45000	1520.00	19.8

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 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 %. A good model should have a large R^2, adj-R^2. Response surface plots were generated with MINITAB Release 15.00.

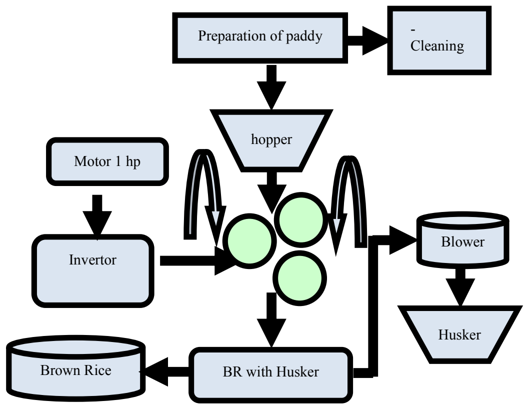

Fig. 2 Diagram of brown rice peeling machine

Response surfaces equations were obtained from design of experiments. Using all values (tests 1 to 42) to the system analysis, the following polynomial equations were generated:

The Estimated Regression Coefficients for brokens using data in uncoded units:

TABLE IV
ANALYSIS OF VARIANCE FOR THE EXPERIMENTAL RESULTS OF THE CENTRAL-COMPOSITE DESIGN

Source	DF	SS	MS	F	P
Blocks	1	27.69	27.686	23.09	0.000
Regression	5	1784.19	356.838	297.54	0.000
Linear	2	544.79	272.397	227.13	0.000
Square	2	1232.94	616.470	514.02	0.000
Interaction	1	6.45	6.453	5.38	0.026
Residual Error	35	41.98	1.199		
Lack-of-Fit	3	30.02	10.007	26.78	0.000
Pure Error	32	11.96	0.374		
Total	41	1853.85			

$$\hat{y} = 1850.63 + (-0.811905) + (-381.613x_1) + (-2.09767x_2) + (153.837x_1x_1) + (0.000731611x_2x_2) + (-0.0458333x_1x_2) \quad (2)$$

Equation (2) is generate the graphic shown in Fig. 3 shows optimal solutions considering Rubber Clearance and Round per minute. Main solutions are positioned at 1440 and 1500 RPM distance and there is a range between 1.2 and 1.5 mm of rubber clearance where it is allowable to use other distances (see Table II. DOE parameter). Result of the analysis of variance is given in Table IV. The test statistic F_0= 26.78 is bigger than the critical $F_{.05,3,32}$ =3.52635 value. There is 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 two factors, 2^2 = 14 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. Effects X_1, X_2, X_1X_1, X_2X_2,X_1X_2 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, round per minute and rubber clearance. The scatter in the residuals at RPM between 1440 and 1500 RPM with rubber clearance at between 1.2 and 1.5 millimeters that the standard deviation of the random errors is the same for the responses observed at each round per minute and rubber clearance.

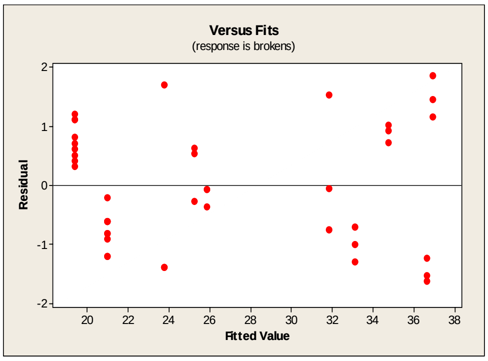

Fig. 3 Residual of Rubber Clearance and RPM

The response taken from Table IV revealed that the square coefficients of rubber clearance (X_1), and round per minute (X_2), have a remarkable effect on the BROKENS yield. Moreover, all the linear and interaction terms of two factor presented in significant effects on the BROKENS yield at 5% probability level. Since all coefficients of the above equation (2) are all negative, the response surface is suggested t have a maximum point in Fig 4. A significantly brown rice peel was observed as moisture and temperature addition increased ($P < 0.05$, Fig. 4). This can be partly attributed to the higher RPM and less rubber clearance of these brown rices. Using low brokens yielded smaller specific volumes, rubber clearance, and subsequently higher RPM values. In Fig.4 presents a graphical representation of one of the response surfaces generated through RSM using a full quadratic model of rubber clearance (X_1), and round per minute (X_2) to predict the BROKENS. As depicted, the normalized search direction to minimize the brown rice is (-1, +1).

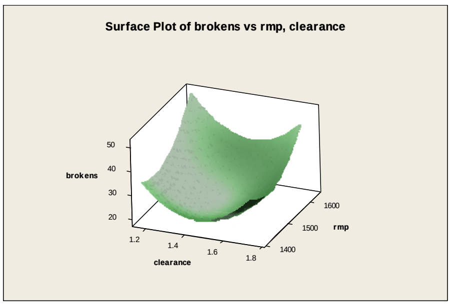

Fig. 4 Response surfaces for the rubber clearance of 1.45 mm. and round per minute of 1480 RPM

IV. Conclusions

The results of this study have clearly indicated RSM is an effective method for optimization of Brokens. Response surface methodology was successfully applied to optimize rubber clearance and round per minute in brown rice that was not paddy. When productions into the formulation, the optimized levels of R-Squire $_{(adjust)}$ was 97.35 % and standard deviation was 1.09513 yielded good quality peeling. This study clearly showed that RSM was one of the suitable methods to optimize the best operating conditions to maximize the peel 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 brown rice established by a central composite design (run order 42) was: rubber clearance 1.45 mm. and round per minute 1480 rpm. The optimal values for the brown rice peeling parameters were brokens rice of 19.02 %.

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