Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/NHUC2

OPTIMIZATION OF PROCESS PARAMETERS FOR PERCENTAGE OF GOOD RICE AND HUMIDITY BY USING TAGUCHI METHOD WITH GREY RELATIONAL ANALYSIS

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ABSTRACT

Optimization of rice cracker processes is essential for achieving of higher productivity in order to remain competitive. This study investigates multi-objective optimization of paddy cracker process for an optimal parametric combination to provide the maximum percentage of good rice (*GR*) with the minimum humidity (*HU*) using the Grey–Based and Taguchi method. Paddy cracking parameters considered are spindle speed, clearance and temperature. Sixteen experimental runs based on Taguchi's L16 (4^3) orthogonal array were performed followed by the Grey relational analysis to solve the multi-response optimization problem. Based on the Grey relational grade value, optimum levels of parameters have been identified. The significance of parameters on overall quality characteristics of the rice cracker process has been evaluated by the analysis of variance (ANOVA) and regression coefficient analysis. Under the assumption of significant confidence.

Keywords: Design of experiment, taguchi method, grey relational analysis, analysis of variance, coefficient

INTRODUCTION

Rice production in Thailand

Rice production in Thailand represents a significant portion of the Thai economy and labor force. In 2017, the value of all Thai rice traded was 174.5 billion baht, about 12.9% of all farm production. Of the 40% of Thais who work in agriculture, 16 million of them are rice farmers by one estimate (Rice production in Thailand, 2021).Thailand has a strong tradition of rice production. It has the fifth-largest amount of land under rice cultivation in the world and is the world's second largest exporter of rice. Thailand has plans to further increase the land available for rice production, with a goal of adding 500,000 hectares (1,200,000 acres) to its already 9.2 million hectares (23 million acres) of rice-growing areas. Fully half of Thailand's cultivated land is devoted to rice (Rice production in Thailand, 2021).

Impact on Farmers

While all of these advances helped improve overall production of rice in Thailand, many low-income farmers in Thailand were left worse off. Many peasants were unable to hold on to their land and became tenants. The UN estimates that Thai farmers who owned their own land declined from 44% in 2004 to just 15% in 2011. The government demanded tax revenues, even during bad years, and this pushed many low-income

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farmers even closer to the margin. Farmers have accumulated 338 billion baht in debt. In 2013, the average household debt in Thailand's northeast was 78,648 baht, slightly lower than the national average of 82,572 baht, according to Thailand's Office of Agricultural Economics (OAE). But the region's average monthly household income, at 19,181 baht, was also lower than the national average, 25,194 baht, according to the National Statistics Office. New technologies have also pushed up the entry cost of rice farming and made it harder for farmers to own their land and produce rice. Many farmers have turned to loan sharks to sustain their operations. In 2015, nearly 150,000 farmers borrowed 21.59 billion baht from these lenders, according to the Provincial Administration Department. Farm debt, mostly incurred by rice farmers, added up to 2.8 trillion baht in 2017. Of Thailand's 21.3 million households, 7.1 million households are farmers. Almost four million Thai households are in debt; 1.1 million of those debtors are farm households (Rice production in Thailand, 2021).

Farmers who already had large scale operations or could afford all the new chemicals, rice strains, and tractors benefited greatly while the average peasant was turned from a land-owning rice producer to a manual laborer on the farms of others.

Varieties

Jasmine (Hom mali) originates in the country and remains the most popular aromatic cultivar. The Rice Department released five new varieties to celebrate the Coronation of Vajiralongkorn, ahead of the Royal Plowing Ceremony a few days later. Each is named "...62" after BE2562. This is a continuation of the tradition of his ancestor, Chulalongkorn, who founded the royal rice varieties competition. This was first held in 1807 and at first was specifically for the Tung Luang and Rangsit Canal districts. The next year it was held at Wat Suthat, and since then has been held at various locations around the kingdom. Vajiravudh continued the royal encouragement of varietal development, founding the Rangsit Rice Experiment Station in 1816 (now called Pathum Thani Rice Research Center and run by the Ministry). Thailand maintains a rice germplasm collection with 24,000 accessions, of which 20,000 are native Thai types (as of 2009), (Rice production in Thailand, 2021).

Therefore, in this research consider the Thai jasmine rice variety (hom mali) was tested to determine the efficiency and to determine the optimal value. How is the relative humidity of paddy different from the Taguchi method and Gray relational analysis.

Study Material

The material used to make the paddy husker will choose the best rice paddy crackers for making.

An experiment to determine the best value for percentage of good rice and humidity with according to the model is shown in Figure 1.

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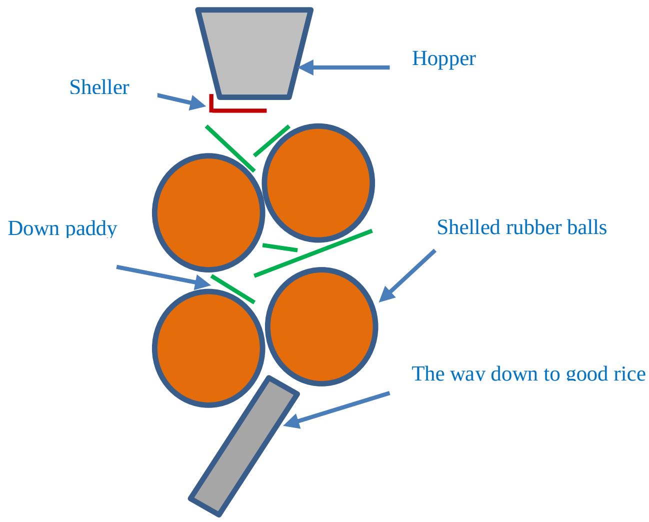

Figure 1 Modeling to test for performance

Taguchi Method

Experimental design by Taguchi method. It is an application of experimental design, control Factors. Factors that cannot be controlled. (Uncontrollable Factor) or noise factor, which these variables are also a source of variation. The influence caused by these variables cannot be eliminated. Therefore, the main function of the Taguchi method is to reduce product variation. By selecting the control factor, the raw experimental results are converted into a signal-to-noise ratio (S/N ratio), which is very important. There are three types of S/N ratio characteristics: small the better type problem, nominal the best type problem, and Larger the Better type problem and the benefit of the Taguchi method is a reduction in the number of trials. This saves time and costs in experimenting. Help make experimenting easier and more convenient. and reliable results make the product more reliable (Surapong Bangphan, 2014).

(Roy, R. K, 2001).

Recently, some researchers have used genetic algorithm, data envelopment analysis, desirability function approach etc. for multi response optimization in various fields of engineering (Md. Israr Equbal et al, 2014). Grey based Taguchi method is a new method forwarded by Deng Ju-long. (1989) from China to solve multi response optimization problems. Deng first proposed grey relational analysis in 1982 to fulfill the crucial mathematical criteria for dealing with poor, incomplete and uncertain systems (Md. Israr Equbal et al, 2014). In recent years grey relational analysis becomes a powerful tool to analyze the processes with multiple performance characteristics. A.K. Sood et al. (2010) studied the effect of process parameters on multiple performance characteristics of FDM build part by using Taguchi method with gray relational analysis. K. Jangraa et al. (2011) optimizes the material removal rate (MRR) and surface roughness simultaneously for WEDM of WC-Co composite by the use of Grey relational analysis. Tarang et al. (2002) utilized the grey-based Taguchi method to optimize the process parameters of submerged arc welding in hard facing, considering

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multiple weld qualities. Huang et al. (2003) successfully optimized the machining parameters in wire EDM using the grey relational analysis along with Taguchi method. Based on the above survey we can conclude that the grey relational analysis is a better approach for optimization of multi response characteristics in different fields. Therefore, grey relational analysis is utilized in this study, for multiple- optimization of the turning machine (metal cutting) according with (Md. Israr Equbal et al, 2014).

Grey Relational Analysis (GRA)

Grey relational analysis (GRA) utilizes a specific concept of information. It defines situations with no information as black, and those with perfect information as white (Chan, J. W. K.; Tong, T. K. L, 2007). Additionally, an analysis of variance (ANOVA) was also utilized to examine the most significant influential factors for the Ra and MRR in the turning process (Franko Puh et al, 2016). Confirmation test was conducted using the optimum cutting parameters determined by the Taguchi optimization method. Based on this analysis, valuable remarks about presented optimization approach are pointed out in the conclusion of this study. Many researchers have studied the effects of optimal selection of machining parameters in turning. According with Franko Puh et al, 2016).

EXPERIMENTAL PROCEDURE

Variable to Study

When the experiment designer knows the number of control factors (Control Factor) and the control factor level (Control Factor Level) for which they are designed. By taking these two values into consideration when choosing an Orthogonal Array, an Orthogonal Array can be used to determine the influence of multiple factors effectively in determining the control factor or variables that are designed in the Orthogonal Array appropriately. as following steps.

Consider the variables affecting the lathe turning process consisting of 3 variables at 4 levels as shown in Table 1. For the variables that do not need to be studied, the method of controlling the variables must be determined to allow the variance due to external factors. The least occurring, such as temperature outside and the experimental site, as well as operators, etc.

Table 1 Control factors.

Control Factors	Experimental Level				Yields	Humidity
	1	2	3	4		
Spindle of Speed (rev/min)	1440	1460	1480	1500	-	-
Clearance (mm)	1.0	1.1	1.0	1.3	-	-
Temperature (Celsius)	25	27	29	31	-	-

Note: The experimental level was set at 4 levels. The 3 factors consisted of the 1, 2,3 and 4 spindle of speeds of 1440, 1460,1480 and 1500 rpm (the turning spindle speed

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of the cracker was between 1440 and 1500 rpm). , The clearance of levels 1, 2,3 and 4 are 1.0,1.1,1.2 and 1.3 mm (normally the optimum feed rates are between 1.0 and 1.2 mm). the temperature are 25, 27,29 and 31degree Celsius (The optimum temperature is between 25 and 27 Celsius). Because the paddy rubber balls used four rubber balls with a diameter of six inches as a medium-sized machine that was tested for efficiency.

Taguchi Method

The Taguchi's robust parameter design is used to determine the levels of factors and to minimize the sensitivity to noise. That is, a parameter setting should be determined with the intention that the product response has minimum variation while its mean is close to the desired target. Taguchi's method is based on statistical and sensitivity analysis for determining the optimal setting of parameters to achieve robust performance (Byrne D.M., and S. Taguchi, 1986). The mean and the variance are combined into a single performance measure known as the Signal-to-Noise (S/N) ratio (Byrne D.M., and S. Taguchi, 1986), The turning machine (metal cutting) were considered the quality characteristic with the concept of "the larger the better". The S/N ratio used for this type response. Assuming the S/N ratio, the goal is the maximum value of the response and is the appropriate value when only the limit tolerances below are listed, which can be obtained is given by:

$$S/N_L = -10\log\left(\frac{1}{n}\sum\frac{1}{y_i^2}\right) \tag{1}$$

Suppose a problem of type the small the better (variance of responses). This assumes the S/N ratio of that target value. A zero response and an appropriate value when detailed just for the upper limit tolerance, can be obtained is given by:

$$S/N_S = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}y_i^2\right) \tag{2}$$

Where n is the number of measurements, and y_i is the measured characteristic value. The mean response for the Grey relational grade with its grand mean and the main effect plot of the Grey relational grade are very important because the optimal process condition can be evaluated from this plot. The dashed line is the value of the total mean of the S/N ratio and mean effect plot. According to the research of (Franko Puh et al, 2016).

A research study was conducted on the factors suitable for turning by tool lathe made of high-speed steel and components of high-carbon alloy steel, using Taguchi method.

The Taguchi Method Experimental Design In this experiment, the factors affecting the turning process of a lathe with a turning knife and the specimens were examined. A total of 3 factors, with each factor having 3 levels. L-9 (3^3) Orthogonal arrays (OAs) were used in the first experiment and the second iteration was performed to confirm the results to determine efficacy. Therefore, the experiment was performed equal to 9 runs, and the total iteration of the experiment was equal to 9 runs or 9 trial sequences. The number of trials depending on the level of the given factors is shown in Table 2

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and Table 3. The Orthogonal L-16 (4^3) Array sequence was used in this study (Roy, R. K, 2001).

Table 2 L-16 (4^3) Orthogonal array.

Trial order	Factors			Yields	Humidity
	SS	CL	TE		
1	1440	1.0	25	-	-
2	1440	1.1	27	-	-
3	1440	1.2	29	-	-
4	1440	1.3	31	-	-
5	1460	1.0	27	-	-
6	1460	1.1	25	-	-
7	1460	1.2	31	-	-
8	1460	1.3	29	-	-
9	1480	1.0	29	-	-
10	1480	1.1	31	-	-
11	1480	1.2	25	-	-
12	1480	1.3	27	-	-
13	1500	1.0	31	-	-
14	1500	1.1	29	-	-
15	1500	1.2	27	-	-
16	1500	1.3	25	-	-

Taguchi Orthogonal Array

Taguchi's orthogonal sequence was designed with 3 variables, 4 levels applied to crackers parameters using Minitab release 20.00 as a calculation aid, shown in Table 3.

Table 3 Taguchi Orthogonal array.

Trial order	Factors			Yields	Humidity
	SS	CL	TE		
1	1	1	1	-	-
2	1	2	2	-	-
3	1	3	3	-	-
4	1	4	4	-	-
5	2	1	2	-	-
6	2	2	1	-	-
7	2	3	4	-	-
8	2	4	3	-	-
9	3	1	3	-	-
10	3	2	4	-	-
11	3	3	1	-	-
12	3	4	2	-	-
13	4	1	4	-	-
14	4	2	3	-	-
15	4	3	2	-	-
16	4	4	1	-	-

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Grey Relational Generation

In Grey relational analysis the first step is to perform the grey relational generation in which the results of the experiments are normalized in the range between 0 and 1 due to different measurement units. Data pre-processing converts the original sequences to a set of comparable sequences. Normalizing the experimental data for each quality characteristic is done according to the type of performance response. Thus, the normalized data processing for MRR corresponding to smaller-the-better criterion can be expressed as: (Franko Puh et al, 2016).

$$x_i^*(k) = \frac{\max\ y_i(k) - y_i(k)}{\max\ y_i(k) - \min\ y_i(k)} \quad (3)$$

The normalized data processing for MRR corresponding to larger-the-better criterion can be expressed as:

$$x_i(k) = \frac{y_i(k) - \min\ y_i(k)}{\max\ y_i(k) - \min\ y_i(k)} \quad (4)$$

where, i = 1, 2, 3, ..., *m*, *m* is the number of experimental runs in Taguchi orthogonal array, in the present work L9 orthogonal array is selected then m = 9. k = 1, 2, ...,n, n is the number of quality characteristics or process responses, in the present work material removal rate are selected, then n = 1 (Franko Puh et al, 2016).

Min y_i (k) is the smallest value of y_i (k) for the k^{th} response. Max y_i (k) is the largest value of y_i (k) for the k^{th} response. x_i (k) is the value after Grey relational generation. The normalized values of material removal rate calculated by Equation (3), (4) respectively (Franko Puh et al, 2016).

Grey Relational Coefficient and Grey Relational Grade

The second step is to calculate the Grey relational coefficient based on the normalized experimental data to represent the correlation between the desired and actual experimental data. The overall Grey relational grade is then computed by averaging the Grey relational coefficient corresponding to each performance characteristic. As a result, optimal combination of process parameters is evaluated considering the highest Grey relational grade by using the Taguchi method. Based on the normalized experimental data the Grey relation coefficient can be calculated using the following equations: (Franko Puh et al, 2016).

$$\xi_i(k) = \frac{\Delta_{\min} + \varsigma\,\Delta_{\max}}{\Delta_{0i}(k) + \varsigma\Delta_{\max}} \quad (5)$$

$$\Delta_{0i}(k) = \left\| x_0(k) - x_i(k) \right\|, \quad (6)$$

$$\Delta_{\max} = \max_{\forall j \in i} \max_{\forall k} \left\| x_0(k) - x_i(k) \right\|, \quad (7)$$

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$$\Delta_{\min} = \min_{\forall j \in i} \min_{\forall k} \left\| x_0(k) - x_i(k) \right\|, \tag{8}$$

where

$\Delta_{0i} = \left\| x_0(k) - x_i(k) \right\|$ is difference of the absolute value between $x_0(k)$ *and* $x_i(k), x_0(k)$ is the reference sequence of the kth quality characteristics (Franko Puh et al, 2016).

$\Delta_{\min}$ *and* $\Delta_{\max}$ are respectively the minimum and maximum values of the absolute differences (Δ_{0i}) of all comparing sequences (Franko Puh et al, 2016).

ζ is a distinguishing coefficient, $0 \leq \zeta \leq 1$, the purpose of which is to weaken the effect of Δmax when it gets too big and thus enlarges the difference significance of the relational coefficient. In the present case, $\zeta = 0{,}5$ is used due to the moderate distinguishing effects and good stability of outcomes (Franko Puh et al, 2016).

The Grey relation coefficient of each performance characteristic. After averaging the Grey relational coefficients, the Grey relational grade y_i can be calculated as follows:

$$\gamma_i = \frac{1}{n} \sum_{k=1}^{n} \xi_i\,(k), \tag{9}$$

where, γ_i = 1, 2, 3 ... 9, (L9 orthogonal array is selected), $\xi_i(k)$ is the Grey relational coefficient of k^{th} response in ith experiment and n is the number of responses. The optimum level of the process parameters is the level with the highest Grey relational grade (Franko Puh et al, 2016).

Then an optimal level of process parameters is determined using higher grey relational grade that indicates the better product quality. To obtain this, average grade values for each level of process parameter is to be find out which can be shown as mean response table. From, mean response table, higher values of average grade values is chosen as optimal parametric combination for multi-responses (Amlana Panda et al, 2016).

After optimal combination is find out, the next step is to perform the analysis of variance (ANOVA) for judging the significant parameters affecting the multi-responses at 95% confidence level and thus giving important information on the experimental data. As the effect of each parameter on multiresponse cannot be assessed by Taguchi method, thus the ANOVA analysis will be helpful to find out the percentage of contribution to identify the effects. The procedure of ANOVA is to separate out the total variability of the response (sum of squared deviations about the grand mean) into each parameter contributions and error (Datta et al, 2008). The P-value (probability of significance) is generally calculated based on F value or Fisher's F- ratio to get the information of significance on the selected response if its value is less than 0.05. The degrees of freedom (DF) are required to evaluate the mean square (MS) and measure the availability of independent information to evaluate sum of squares (SS). In an

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ANOVA analysis, mean square deviation and F-value is calculated by MS = SS/DF and F = MS for a source parameter/MS for the error (Amlana Panda et al,2016).

After optimal combination of process parameters are found out, the next step is very the improvement of Grey relational grade through conducting confirmatory experiment. The predicted value of Grey relational grade for optimal level can be obtained as follows,

$$\hat{\gamma} = \gamma_m + \sum_{i=1}^{0} \left(\bar{\gamma} - \gamma_m\right), \tag{10}$$

where γ_m is the total mean grey relational grade, $\bar{\gamma}_i$ is the mean grey relational grade at the optimal level of each parameter, and o is the number of the significant process parameters (Sahoo & Sahoo,2013).

The higher value of the Grey relational grade corresponds to an intense relational degree between the reference sequence $x_0(k)$ and the given sequence $x_i(k)$. The Grey relational coefficients and Grey relational grade calculated by Equation (5), (8) respectively. The highest Grey relational grade is the rank of 1. Therefore, the experiment number 5 is the best combination of turning parameters for material removal rate among the nine experiments (Franko Puh et al, 2016).

The multi-objective optimization problem has been transformed into a single equivalent objective function optimization problem using Grey relational analysis. Accordingly, optimal combination of process parameters is evaluated considering the highest Grey relational grade by using the Taguchi method. According to the research of (Franko Puh et al, 2016).

RESULTS AND DISCUSSION

The efficiency of the four rubber paddy Sheller's was studied.

Study of four rubber paddy hullers using 220 volts of electricity. The efficiency of the yields and humidity according to the design conditions was tested by the Taguchi method for all sixteen experiments. Rice crackers time is recorded by timing and measuring the final value of all crackers paddy operations. The yields and humidity was calculated using the relationship between (The efficiency of paddy Sheller with rubber ball type paddy Sheller) and from the analysis, it was found that the experiment that achieved the optimum conditions as experiment 2, with the first factor being: The spindle of speed is 1440 rpm, the second factor is the clearance of 1.1 mm and the third factor is the 27 Celsius distance. The maximum of yields is 0.95 percentage of good rice. The remaining trials for each factor at each level are shown in Table 4.

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Table 4 The value obtained from the first observation.

Trial order	SS	CL	TE	Yields	Humidity
1	1440	1.0	25	0.92	**0.55**
2	1440	1.1	27	**0.95**	0.57
3	1440	1.2	29	0.75	0.59
4	1440	1.3	31	0.70	0.61
5	1460	1.0	27	0.88	0.57
6	1460	1.1	25	0.93	0.55
7	1460	1.2	31	0.73	0.61
8	1460	1.3	29	0.70	0.59
9	1480	1.0	29	0.89	0.59
10	1480	1.1	31	0.92	0.61
11	1480	1.2	25	0.69	0.55
12	1480	1.3	27	**0.64**	0.57
13	1500	1.0	31	0.83	**0.61**
14	1500	1.1	29	0.90	0.59
15	1500	1.2	27	0.67	0.57
16	1500	1.3	25	0.65	0.55

Note:

SS = Spindle of speed (rpm)

CL = Clearance (mm)

TE = Temperature (Celsius)

Result Analysis

After determining all the observed values as shown in Table 4. The S/N ratios and mean values were calculated and heterogeneous graphs were analyzed by the Minitab release program. 20.00 The S/N ratio for the yields and humidity was programmed. Minitab release 20.00 by Taguchi method, which in this research will be based on a total analysis by Taguchi method by deciding the main effect for process parameters. The operation was performed with Analysis of Variance (ANOVA), and regression coefficient analysis, decision coefficient and the best parameter setting. The main effect analysis was used in this study, the trend for each factor effect is shown in Figure 2 and Figure 3 respectively. Rice cracker machine performance is a key factor of the individual L-16(4^3) variance analysis, which can be calculated by forecasting. The calculation of coefficients and analysis of variance are shown in Tables 5 and Table 6 respectively.

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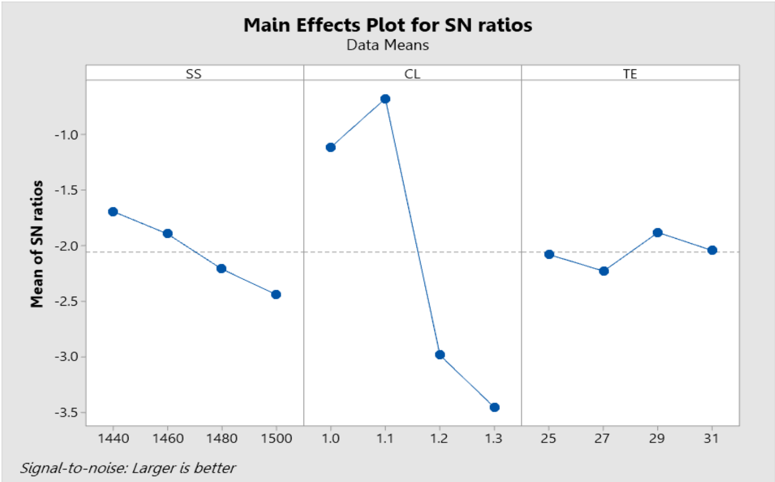

Figure 2 Main effects plot for S/N Ratio (Yields)

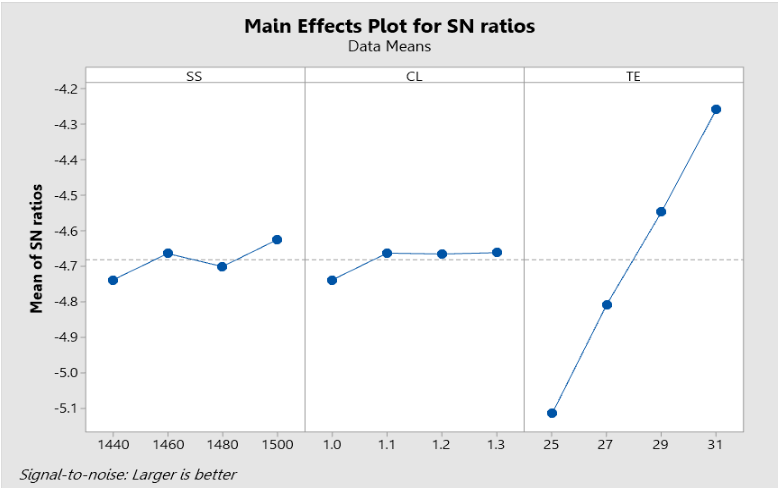

Figure 3 Main effects plot for S/N Ratio (Humidity)

Table 5 Coefficient model coefficients for S/N Ratios.

Estimated Model Coefficients for Means				
Term	Coef	**SE Coef**	**T**	**P**
Constant	-2.05803	0.03008	-68.414	0.000
SS 1440	0.36639	0.05210	7.032	0.000
SS 1460	0.16497	0.05210	3.166	0.019
SS 1480	-0.15093	0.05210	-2.897	0.027
CL 1.0	0.94173	0.05210	18.074	0.000
CL 1.1	-0.92543	0.05210	-17.761	0.000
CL 1.2	-0.92543	0.05210	-17.761	0.000
TE 25	-0.02180	0.05210	-0.418	**0.690**
TE 27	-0.16966	0.05210	-3.256	0.017
TE 29	0.17699	0.05210	3.397	0.015
S = 0.1203 R-Sq = 99.64% R-Sq(adj) = 99.10%				

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From Table 6, the coefficient results for the S/N ratios of the turning process at a significant level of 5% (0.05) are significant for the three factors of the rice crackers process at a significant level, 5% (0.05) is the significant temperature. The remaining three factors were significant for the rice crackers process in this study.

Table 6 ANOVA for S/N ratios.

	Analysis of Variance for S/N ratios					
Source	**DF**	**Seg SS**	**Adj SS**	**Adj MS**	**F**	**P**
SS	**3**	1.3158	1.3158	0.43861	30.29	0.001
CL	3	22.3719	22.3719	7.45731	515.05	0.000
TE	3	0.2432	0.2432	0.08106	5.60	0.036
Residual Error	6	0.0869	0.0869	0.01448		**(significant)**
Total	15	24.0178				

Analysis of variance (ANOVA) table is formulated considering grey relational grade value which has been shown in Table 6. This table gives the significance of process parameters on multi-responses. From the ANOVA table, it is revealed that feed is the insignificant process parameters affecting multi responses as its p-value is more than 0.05 at 95% confidence level. Spindle speed, feed rate and depth of cut does not show any significance on responses simultaneously. According to the research of (Amlana Panda et al, 2016).

The coefficient estimation model for the S/N ratio, the constant P-Value of 0.004, and the adjustment of the decision coefficient of 99.10 % are shown in Table 5. The P-Value P- Value of the S/N ratio is shown in Table 5. The value of 0.001, 0.000 and 0.036 is shown in Table 6 . The regression coefficient for the percentage of good rice (yields) and humidity S/N ratio is

$$Yields = -2.05803 + SS\ 1440\ (0.36639) + SS\ 1460\ (0.16497) + SS\ 1480\ (-0.15093) + CL\ 1.0\ (0.94173) + CL\ 1.1(-0.92543) + CL\ 1.2(-0.92543) + TE\ 25(-0.02180) + TE\ 27(-0.16966) + TE\ 29(0.17699) \quad (11)$$

$$Humidity = 0.583750 + SS\ 1440\ (-0.003750) + SS\ 1460\ (0.001250) + SS\ 1480\ (-0.001250) + CL\ 1.0\ (-0.003750) + CL\ 1.1(0.001250) + CL\ 1.2(0.001250) + TE\ 25(-0.028750) + TE\ 27(-0.008750) + TE\ 29(0.008750) \quad (12)$$

Multi-Objective Optimization Using Grey Relational Analysis

The grey correlation analysis is used to optimize the rice crackers, yields and humidity all together. The basic steps are: performing dimensionless processing on the test results; analyzing the results of the dimensionless processing to obtain the grey correlation coefficient; solving the average grey correlation coefficient to obtain the grey correlation degree (Shi K, Zhang D and Ren J, 2015).

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Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
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DOI 10.17605/OSF.IO/NHUC2

Implementation of Methodology to Find Multi-Response Parametric Optimization

The experimental data have been normalized for both flank wear and surface roughness using Equation (3) and presented in Table 7 called grey relational generations.

Table 7 Grey relational generation values.

Run No.	Yields	Humidity
	Larger the better	
Ideal sequence	1	1
1	0.097	1.000
2	0.000	0.667
3	0.645	0.333
4	0.806	0.000
5	0.226	0.667
6	0.065	1.000
7	0.710	0.000
8	0.806	0.333

Table 7 (cont.) Grey relational generation values.

Run No.	Yields	Humidity
	Larger the better	
Ideal sequence	1	1
9	0.194	0.333
10	0.097	0.000
11	0.839	1.000
12	1.000	0.667
13	0.387	0.000
14	0.161	0.333
15	0.903	0.667
16	0.968	1.000

From the normalized data set of Table 7, Grey relational coefficients have been computed using Equation 5. The value of distinguishing coefficient is taken as 0.5 as equal weighting has been given to both quality characteristics. The results are shown in Table 8. Next, Grey relational grade (GRG) has been found out using Equation 5 from the results of grey relational coefficients. The result of GRG is presented in Table

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DOI 10.17605/OSF.IO/NHUC2

10. This result is utilized for optimizing the multi-responses as it is converted to a single grade. According to the research of (Amlana Panda et al., 2016).

Table 8 Grey relational coefficients and grey relational grade values.

Run	Evaluation of Δ_{0i} (Yields)	Evaluation of Δ_{0i} (Humidity)	Grey relational coefficient (Yields)	Grey relational coefficient (Humidity)	GRG (Yields)	GRG (Humidity)	Rank	
	1	1	1	1	1	1	Y	H
1	1.000	0.333	0.356	1.000	0.630	0.500	3	9
2	0.355	0.667	0.333	0.600	0.667	0.467	1	13
3	0.194	1.000	0.585	0.429	0.470	0.548	11	5
4	0.774	0.333	0.721	0.333	0.457	0.667	15	1
5	0.935	0.000	0.392	0.600	0.583	0.467	7	13
6	0.290	1.000	0.348	1.000	0.642	0.500	2	9
7	0.194	0.667	0.633	0.333	0.461	0.667	13	1
8	0.806	0.667	0.721	0.429	0.457	0.548	15	5
9	0.903	1.000	0.383	0.429	0.595	0.548	6	5
10	0.161	0.000	0.356	0.333	0.630	0.667	3	1
11	0.000	0.333	0.756	1.000	0.459	0.500	14	9

Table 8 (cont.) Grey relational coefficients and grey relational grade values.

Run	Evaluation of Δ_{0i} (Yields)	Evaluation of Δ_{0i} (Humidity)	Grey relational coefficient (Yields)	Grey relational coefficient (Humidity)	GRG (Yields)	GRG (Humidity)	Rank	Run
	1	1	1	1	1	1	Y	H
12	0.613	1.000	1.000	0.600	0.500	0.467	9	13
13	0.839	0.667	0.449	0.333	0.531	0.667	8	1
14	0.097	0.333	0.373	0.429	0.606	0.548	5	5
15	0.032	0.000	0.838	0.600	0.467	0.467	12	13
16	1.000	0.333	0.939	1.000	0.486	0.500	10	9

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From the value of GRG, the effects of each process parameters at different levels are plotted and shown in Fig. 5 and mean grey relational grade is presented in Table 4. The optimal parametric combination is chosen based on higher mean grey relational grade values from Table 9. The higher value of grey relational grade implies a stronger correlation to the reference sequence and better performance. Thus, the optimal settings for multi-responses becomes SS1-CL2-TE2 i.e. spindle speed of 1440 rpm, clearance of 1.10 mm, and temperature of 27 Celsius respectively. The higher values of mean grey relational grade shown in Figure 4 and Figure 5 gives the minimum values of flank wear and surface roughness. The difference of maximum and minimum values of mean GRG for rice cracker parameters were as 0.090 for spindle speed of 1440 rpm, clearance of 1.10 mm, and temperature of 27 Celsius respectively shown in Table 9. This result indicates that the feed rate has the most influencing effect on multi-responses compared to crackers in rice cracker operation. The sequence of importance of process parameters on multi-responses are feed rate > spindle speed > depth of cut. According to the research of (Amlana Panda et al, 2016).

Table 9 Main effects on mean grey relational grade.

Factors	**Mean Grey relational grade**				**Max-Min**	**Rank**
	Level 1	**Level 2**	**Level 3**	Level 4		
SS	0.8300	0.8100	0.7850	0.0675	0.763	2
CL	0.8800	0.9250	0.7100	0.6725	0.253	1
TE	0.7975	0.7850	0.8100	0.0250	0.785	3

Total mean grey relational grade = 0.675

Figure 4 Main effect plot of grey relational grade (Yields)

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Figure 5 Main effect plot of grey relational grade (Humidity)

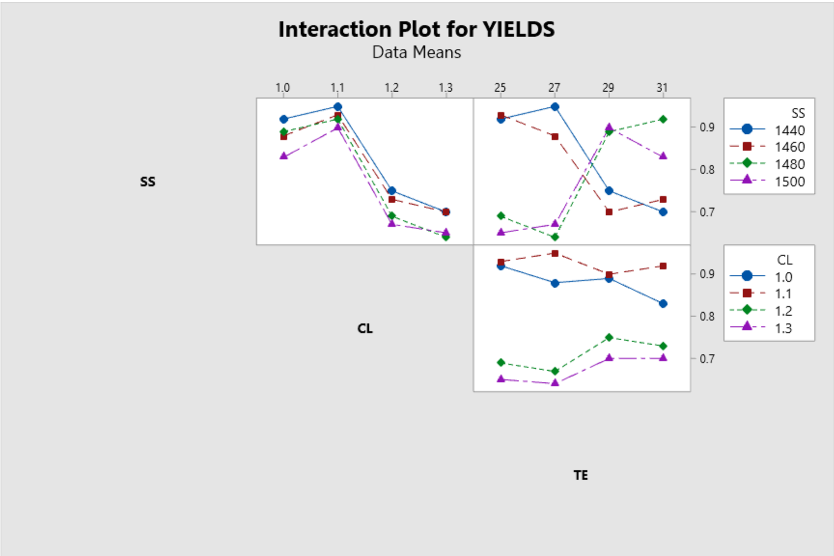

Figure 6 Interaction plots of yields (Yields)

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Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
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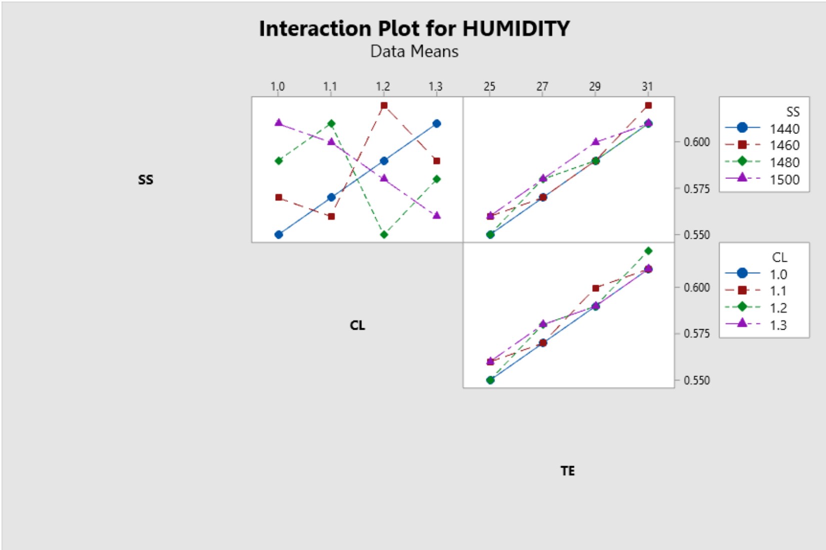

Figure 7 Interaction plots of yields (Humidity)

To analyze the factor response from the gray correlation analysis, the result was selected from the mean of the greatest average gray relation grade in the. Each level of that variable. Therefore, from Table 9, the conditions for rice crackers are suitable: Configure the variable speed at level 1 (1440 rpm), clearance at level 2 (1.1 mm), and temperature at level 2 (27 Celsius). The above factor values can be used to test and predict the turning results of the paddy from the Taguchi equation above. To compare the experimental results obtained as shown in Table 10.

Table 10 Taguchi prediction experiment and relative analysis Gray.

methodology	Response		Factors	Optimal value
Taguchi method	Yields	Humidity	SS_1, CL_2, TE_2	0.874(Y), 0.562(H)
Grey relational analysis	Yields	Humidity	SS_1, CL_2, TE_2	0.914(Y), 0.545(H)

Note: Y = Yields, H = Humidity

Conclusion

The analysis of variance (ANOVA) for GRG indicated that the p values of all parameters were less than 0.05 and, hence, significant. Finally, confirmation tests were performed to verify the improvement of 4.0% in GRG, from 0.874 for the initial design parameters (SS1, CL2, TE2), to 0.914 for the optimal parameters (SS1, CL2, TE2).

Based on the rice cracker tests of jasmine rice, the signal-to-noise ratio analysis method and the grey correlation analysis method were employed to acquire process

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parameters combination of the optimal yields (percentage of good rice) and the optimal humidity, it can be concluded as follows:

(1) Crackers play the most significant effect on yields and humidity. The rice cracker parameters combination with the best percentage of good rice is that 95% (maximum), SS = 1440 rpm, CL = 1.10 mm, and TE = 27 Celsius. Meanwhile, the processing parameters combination with the minimum humidity is that SS = 1440 rpm, CL = 1.10 mm, and TE = 27 Celsius.

(2) To achieve both the maximum and minimum crackers and humidity respectively, and the most appropriate process parameters is SS = 1440 rpm, CL = 1.10 mm, and TE = 27 Celsius.

(3) The suitability of multi-objective optimization was confirmed through experimentation. The analogy is proposed as a medium for solving the problem of parameter selection under multi-objectives in an efficient manufacturing and workshop.

Therefore, the gray correlation analysis method can be combined and used to optimize the crackers parameters. It is another technique that can be applied. For selecting the appropriate variable in the case of a many results are responsive, with fewer trial methods that require repeated experimentation, such as response surface methods.

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