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Application of Taguchi Method for Optimization of Parameter in Improving Soybean Cracking Process on Dry Process of tempeh Production

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Abstract. Taguchi method is a Design of Experiment approach for parameter optimization of a process. The purpose of this study is to determine the optimum parameters and the most influential parameters in the process of soybean cracking in the dry process of tempeh production. In the process of cracking the dry soybeans found a defect of 14.5%. after applying the Taguchi method and obtaining the optimum parameters, the defect on the dry process of cracking the dry soybeans is reduced to 6.6%. Determination of parameters and levels, objective functions, orthogonal array, signal-to-noise ratio, and analysis of variance (ANOVA) will be done in this study to improve the performance of the soy-cracking process. In this study there are three parameters used in conducting experiments with Taguchi method, three parameters namely distance between stones, hopper outlet diameter, and sun-drying duration. The results of this study are: distance between stones with setting optimum 1mm and percentage contribution 13%; hopper outlet diameter with setting optimum 25mm and percentage contribution 85%; and sun-drying duration with drying optimum 1 day and percentage contribution 2%. the most influential parameter is the hopper outlet diameter in the soybean cracking process, as it determines the soybean discharge that goes into the cracking phase.
Keywords: optimization parameter, Taguchi method, Dry process, Tempeh

1   Introduction

Design of experiments (DOE) is one of the powerful tools used to investigate deeply hidden causes of process variation. DOE techniques are useful for surfacing the effects of hidden variables, and studying possible effects of variables during process design and development. Experiments range from uncontrollable factors introduced randomly to carefully controlled factors [1]. The Taguchi experimental design reduces cost, improve quality, and provides robust design solutions. The advantages of Taguchi method over the other methods are that numerous factors can be simultaneously optimized and more quantitative information can be extracted from fewer experimental trials. [2]. Taguchi proposed using the signal-to-noise (S/N) ratio to measure the quality characteristics that deviated from the designed parameters [3]. Initially developed to improve the quality of manufactured goods (development of manufacturing process), then the application is extended to many other fields in Engineering, such as Biotechnology [4]. The Taguchi method involves identifying the appropriate control factors to obtain optimal results from the process. Orthogonal Arrays (OA) are used to perform a series of experiments.

The results of this experiment were used to analysis the data and predict the quality of the resulting components [5].

This study will apply the Taguchi method to improve the quality of the soybean cracking process in the dry process of soybean production. In the dry process of soybean production, which was initially broken down in wet conditions, using a dry soybean crusher, the soy bean was split dry. Soaking and boiling of soybeans is done after the cracking process using this machine. Therefore, the soybeans are split into 2 and the epidermis are separated in a dry state. The following figure 1 is a flowchart of the dry process of soybean production.
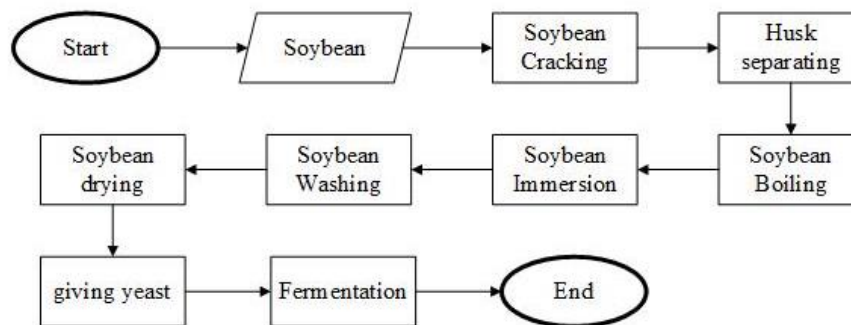

Figure 1. Dry Process of Tempeh Production.

Production of tempeh by using dry process known there is defect at result. Defect on the dry process of tempeh production occurs due to the nonconformity of soybean processing with Critical to Quality (CTQ). The CTQ analysis is done to achieve a high level of understanding of what is important to the success of the process [6]. Critical to Quality (CTQ) elements that directly relate to the needs and satisfaction of the exporter [7]. Tempe production is a field of great interest by SMEs residing in Indonesia. In Indonesia SMEs are scattered in various regions, the existence of SMEs is very dominant, especially in Java, especially in Bandung [8].

The result of application of Taguchi method is the optimum parameter on soybean cracking process. After obtaining the S/N ratio, this study will calculate the Analysis of Variance (ANOVA). ANOVA is a statistical model for comparing differences among means over two populations [9]. The nature of ANOVA is the sum of the squares SS_t (total variation) equal to the sum of the squares of the deviations of all parameters [5]. In this study ANOVA calculation aims to get percentage contribution of the most influential parameters.

2   Methods

2.1   Taguchi Method

Design of Experiment (DOE) is an approach often used in product development. Design of Experiment (DOE) is based on the principles of experimental design, equations or mathematical models and the result of these factors [10]. One method that uses the DOE approach is the Taguchi method. The Taguchi method was developed by Genichi Taguchi to analysis the effect of the experimental parameters and determine the optimal process parameters [11]. Taguchi suggested engineers to use orthogonal arrays of control and level factors to design experiments [12]. This method can not only reduce the experimental cost but also improve the reliability of the results of the analysis. In this method, the signal-to-noise ratio (S/N ratio) is used to analysis the contribution of each experimental data. The S/N ratio can be calculated in accordance with nominal-the-best, smaller-the-better, and larger-the-better [12].

2.2   Step of Taguchi Method

There are the steps involved of the Taguchi method [5]:
  a. Identify main functions & Quality Characteristics

b. Identification of Objective Function
c. Identify parameters & levels
d. Selection of Orthogonal Array design
e. Conduct Experiment
f. Calculation of Signal-to-Noise

2.3   Analysis of Variance

Analysis of Variance (ANOVA) is the most commonly used method for GR & R analysis. ANOVA for GR & R is performed with operator N number and M number of random parts. The sections are labeled first for purpose and the operator will perform the measurement of the parts with the L number of replication. For a certain degree of trust, Minitab can calculate from operator, from part-to-part, from measurement equipment (repetition), and from interaction between operator and spare parts. R & R is the number of repetitions and reproducibility [6]. In search of various parameters by calculating the total of the sum of squares (SSt). Here is a solution for finding SS. Here is the equation of calculating SSt [7].

$$SSt = \sum_{i=1}^{n}(\bar{x}_i - \bar{\bar{x}}) \tag{1}$$

2.4   Cracking Soybean Process

In the process of cracking soybeans there are 5 stages passed for soybeans to break. 5 stages are soybeans entering the hopper, drainage to screw conveyor, drainage toward cracking, soy cracking, and product streaming. The following figure 2 is a transparent box of soybean breakers.
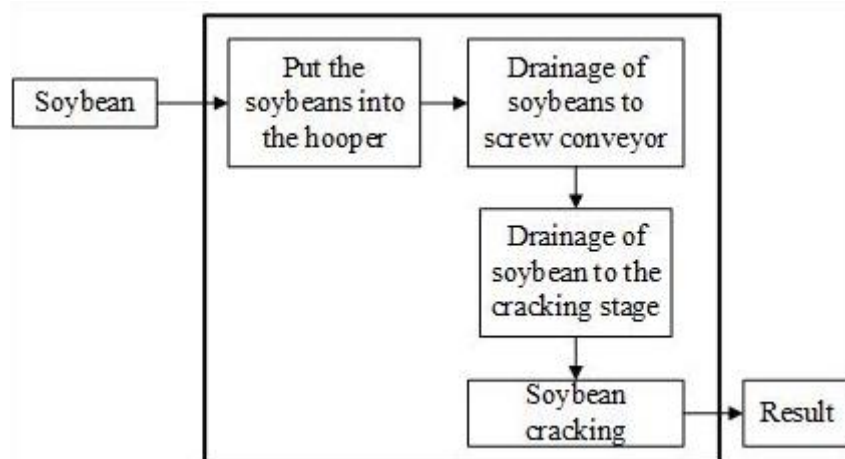

Figure 2. Transparent Box of Soybean-Cracking Machine.

In the dry process of tempeh production, soybeans are broken down using soy-cracking machine. The machine produced by Rumah Tempe Indonesia is made of Stainless steel. Machines in general have 3 main parts, namely prime mover, power transition, and rotation motion. In a soybean-cracking machine, the originator is an AC dynamo with a power of 220 V. The power transition used is a belt pulley. And the movement is a screw conveyor and grinding wheels. Screw conveyor serves to push soy into the cracking part. Grinding stone serves to break the soybeans into 2 parts. Here figure 3 is a schematic image of a soy breaker machine.
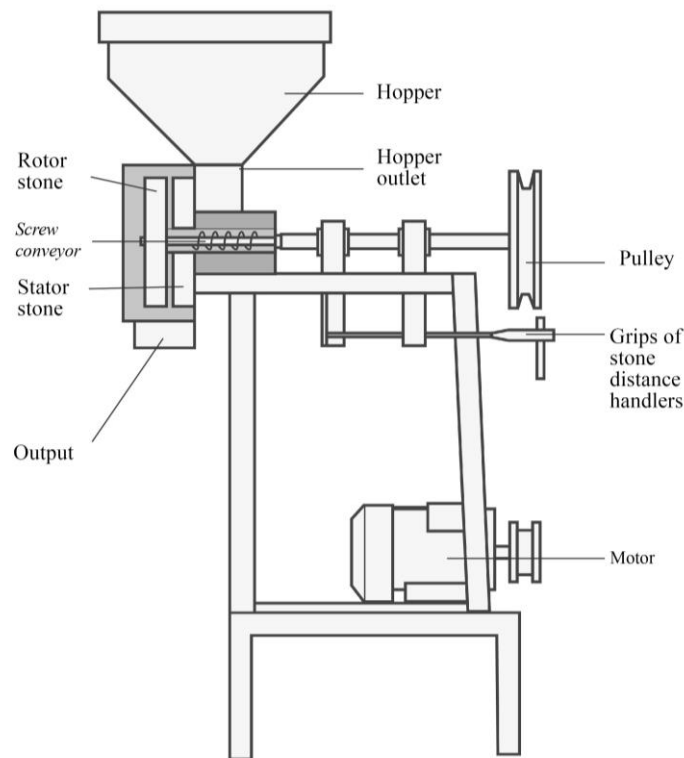
Figure 3. Schematic of Soybean-cracking Machine.

In the soy-cracking process, soybeans will be fed through the hopper. Then the soybean will fall to the screw conveyor through the hopper hole. Screw conveyor will push the soybean to the grinding stone. The grinding wheel will break the soybeans into 2 parts. Then the split result will fall to the resulted splice channel. The distance between the grinders can be adjusted using the grinding wheel handle.

3   Result and Discussion
Identify Main Function & Characteristics Quality
Main Function   : Soybean-cracking process
Characteristic Quality   : Defect
Testing Tools   : Scales
The main function is the process done in the application of Taguchi method in conducting experiments. Characteristic quality is the response to be calculated. Testing tools are tools that are calculated to measure response.

3.1   Identify Objective Function

The purpose of this study is to minimize the defect which means the smaller the defect is identified the better the quality of the splitting process. Therefore, the objective function in this study is smaller-the-better. Here is the formula used to calculate S/N ratio smaller-the-better [5].

$$Signal\ to\ noise = -10\log_{10}(\frac{1}{n}\sum_{i=1}^{n} y_i^2) \qquad (2)$$

3.2   Identify Parameter & Level

The parameters and levels are determined to experiment with the Taguchi method. Based on brainstorming with researchers and expert operators of soybean cracking machine, obtained parameters and levels presented in table 1.

Table 1. Parameter and Level.

Parameter	Level 1	Level 2	Level 3
Distance between stone	1 mm	0,9 mm	0,8 mm
Hopper outlet diameter	21 mm	19 mm	25 mm
Sun-drying duration	0 day	1 day	3 day

3.3   Selection of orthogonal array design

Selection of orthogonal array design using Minitab software. The number of parameters and the number of each level entered to obtain the choice of orthogonal array design. The orthogonal array design to be used is orthogonal array L9 which will be simulated 3 times experiment on soybean cracking process. The following table 2 is an orthogonal array design used.

Table 2. Orthogonal Array.

Experiment	Parameter 1	Parameter 2	Parameter 3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

3.4   Experiment

At this stage experiments will be conducted based on selected orthogonal arrays. Each experiment on an orthogonal array will be performed three times to calculate the noise factor interference. The following Table 3 is the result obtained from conducting the experiments performed. Response or result of defect that happened from soybean cracking process.

Table 3. Response of Experiment Result.

Experiment	Trial 1	Trial 2	Trial 3	Mean
1	85	70	70	75
2	205	165	170	180
3	60	90	60	70
4	105	95	90	96.67
5	240	250	245	245
6	110	100	95	101.67
7	120	115	120	118.33
8	330	340	360	343.33
9	110	70	80	86.67

Below figure 4 is a Design of Experiment from the experiments conducted on this study. Design of Experiment is a stage that is done when doing experiments. DOE is performed 9 times according to the number of combinations of orthogonal array tables that have been designed.
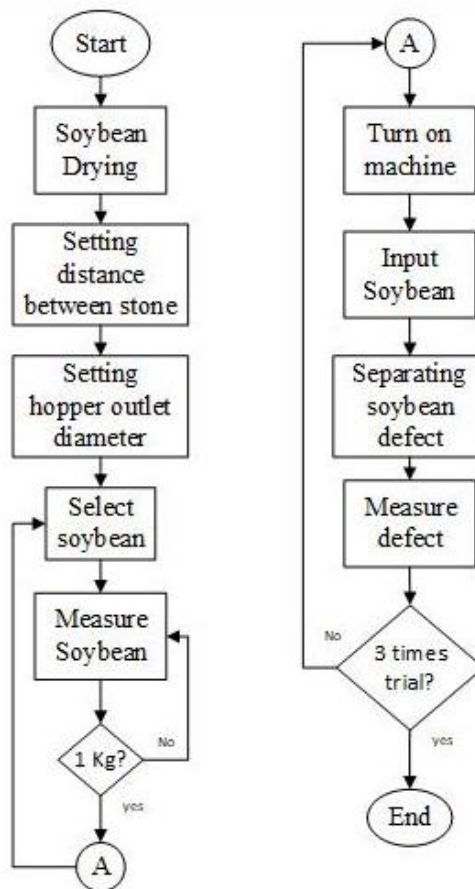
Figure 4. Design of Experiment.

3.5   Examine Data; predict the optimum parameter levels and its percentage contribution

Since the objective function of the soybean-cracking process is smaller-the-better, the S/N ratio calculation is performed with the smaller-the-better equation. The following table 5 is the calculation of the S/N ratio of each experiment.
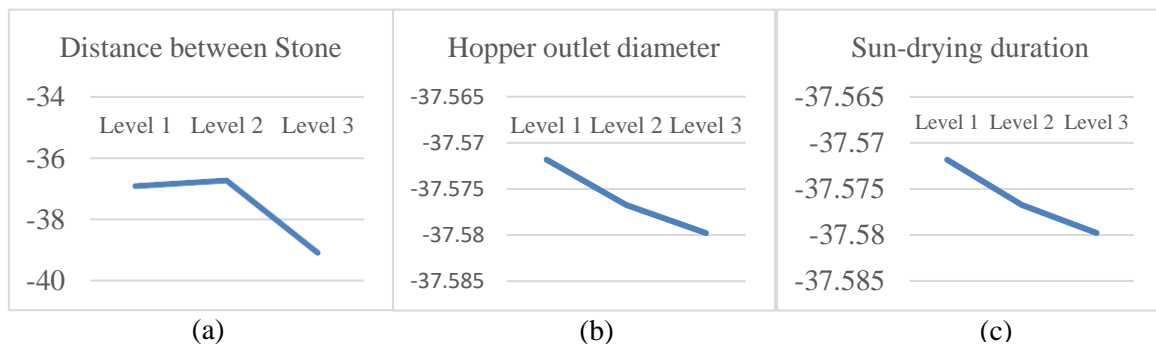
Table 4. S/N Ratio Experiment.

Experiment	S/N Ratio
1	-37.540
2	-45.148
3	-37.076
4	-39.724
5	-47.785
6	-40.160
7	-41.464
8	-50.720
9	-38.921

After obtaining S/N ratio from each experiment, then calculate S/N ratio from each level of each factor.This study use Minitab software to calculate S/N ratio which the data to be process is response of experiment. The following table 6 is the calculation of the S / N ratio and figure 5 is the graphic of each S/N ratio parameter.

Table 5. Result of S/N Ratio.

Level	Distance between stones		Hopper outlet diameter		Sun-drying duration	
	Total	Average of S/N Ratio	Total	Average of S/N Ratio	Total	Average of S/N Ratio
1	-119.76	-39.92	-118.73	-39.58	-128.42	-42.81
2	-127.67	-42.56	-143.65	-47.88	-123.79	-41.26
3	-131.10	-43.70	-116.16	-38.72	-126.32	-42.11

Figure 5 Graphic S/N ratio of (a) Distance between stone, (b) hopper outlet diameter, and (c) Sun-drying duration.

The optimum parameters are selected based on the value of the highest S / N ratio. Based on the above graph, the optimum parameter in soybean cracking process is shown in table 7.

Table 6. Parameter Optimum.

Parameter	Optimum Value
Distance between stones	1 mm
Hopper outlet diameter	25 mm
Sun-drying duration	1 day

The calculation of the analysis of variance is done to obtain the percentage of contribution parameters to obtain the most influential parameters of the parameters undertaken trials. Here is the result of SSt calculation shown by table 8.

Table 7. Result of ANOVA.

Parameter	SS	SS%
Distance between stones	7.51	13%
Hopper outlet diameter	51.25	85%
Sun-drying duration	1.19	2%
Total	59.96	100%

From the table above can be seen in the process of solving soybean parameters that affect the occurrence of defect is the percentage of 13% grinding distance between grinding, hole hopper diameter 85%, and duration of soybean 2%.

4   Conclusion

This journal applies Taguchi method for parameter optimization in soybean cracking process on dried production process of tempeh. Here are the conclusions based on the experimental results that have been

done in this journal: In the soybean cracking process the most influential parameter is the hopper outlet diameter as it determines the soybean discharge that goes into the cracking phase; The application of the Taguchi method can perform experiments more efficiently for parameter optimization of a process.

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