Taguchi method application to improve the quality of coffee pulp screen printing products

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Abstract. One of the main reasons consumers choose a product is based on quality. Consumers will choose products that have the quality as expected and in accordance with the benefits obtained. This is the basis for conducting research on Coffee Pulp Screen Printing products. The study was conducted with the Taguchi Method to determine the optimal combination of color parameters produced by coffee pulp screen inks. The parameters studied were Coffee Pulp as a factor A, the amount of Water as a factor B, the amount of vinegar as factor C and the length of cooking time as a factor D. experiments were carried out with two levels and two values for each factor. In this experiment using orthogonal array L8 (27) with two replications. The results of the analysis were processed using S/N average and variability ratios. Based on the result of these experiments it was found that the factors that significantly influence the color quality of coffee plup screen printing ink are coffee plup 0,5 kg, 0,5 liter water, 100 ml vinegar, and 15 minutes cooking time. The results of the experiment show the optimal combination to get a dense color on the results of coffee grounds.

1. Introduction
Garment products are one of the commodities with great potential to be developed in the global market. Since 2010, exports of apparel from Indonesia abroad, especially to Europe, have increased again [1]. That process is an opportunity for the garment industry in Indonesia to develop into a flagship. One of the growing garment businesses is the screen printing business. This business has the potential to become a superior business, because it is supported by the needs and awareness of the community's appearance.

One of the natural ingredients used for making screen printing inks is Coffee Pulp. Coffee pulp is used as the basis for making screen printing ink because it has a deep black color and is suitable as a base material for ink. Coffee pulp is waste disposal from the results of making or filtering coffee. Coffee screen printing ink has a composition ranging from coffee grounds, vinegar and water. Ink pulp coffee grounds itself is a water-based screen printing ink and consists of natural ingredients so there are no harmful ingredients contained therein.

2. Methods
Coffee pulp screen printing products are products that are still in research and development, of course there are still some problems that arise in the results of coffee pulp screen printing ink. One of the problems is the lack of color produced by the screen printing ink on the screen printing results due to the lack of proper standardization of the composition for coffee pulp screen printing inks. problem
solving for this coffee pulp screen printing product can be done with the help of the taguchi method which serves to determine the most influential factors and the best combination to improve product quality. The taguchi method itself is a method that has the aim of improving product quality at the same time reducing costs and resources to a minimum. The taguchi method is also an efficient method because it is possible to carry out research involving many factors and quantities and produce conclusions regarding the response of the factors and levels of control factors that produce the optimum response [2].

Based on previous research, taguchi method is a method that can improve quality, productivity [2] and also the method has aims to reduce costs and resources to a minimum [3]. Taguchi method is also very effective in determining the right combination of factors or composition of a product, because it involves many factors [4][5][6].

The steps in implementing the taguchi method according Soejanto [2] are:
1. Formulate / define the problem that will be investigated in the experiment.
2. The goals that underlie the experiment must be able to answer what has been stated in the formulation of the problem, namely looking for the cause that becomes the effect on the problem that we observe. This search is done systematically
3. Identification of Factors (Independent Variables) using causal diagrams.
4. Separation of Control Factors and Disruption Factors
5. Determination of the Number of Levels and Level Factor Values, this is important for
6. The accuracy of the results of the experiments and the costs of conducting the experiments.
7. Calculation of Degrees of Freedom
Dof for factor \( A = nA - 1 \) 
Dof for the interaction of factors A and B = (nA - 1). (NB - 1) 
Total number Dof = (nA - 1). (NB - 1) + (nA - 1). (NB - 1)  
8. The choice of an appropriate orthogonal matrix depends on the factor and interaction values expected and level values of each factor.
9. Placement of Columns for Factors and Interactions into the Orthogonal Matrix
10. Preparation and Implementation of Experiments. Implementation of experiments includes determining the number of replication experiments and randomization of the implementation of experiments.

a. Number of Replication carried out with the aim of:
\- Increase accuracy of experimental data
\- Reduces the error rate in experiments
\- Obtain an estimated price of experimental error so as to enable a significant test of experimental results to be held.

b. Randomization
11. Analysis of the Taguchi Variant. For a two-way analysis of variance the requirement that must be met is that the experimental data must consist of two factors or more and two or more levels.

\[ S_T \] - Total Squares.
\[ SS_T = \sum_{i=1}^{n} y_i^2 \] (2)

\[ S_A \] - Number of Factor A Squares
\[ SS_A = \left[ \sum_{i=1}^{K_A} A_i^2 - \frac{T^2}{n} \right] \] (3)
S\textsubscript{AXB} - number of AxB interactions

\[ S_{AXB} = \frac{(\text{Total AxB})^2}{n_1} + \frac{(\text{Total AxB})^2}{n_2} - \frac{(\text{Total AxB})^2}{n_1 + n_2} \]  

(4)

SS\textsubscript{e} - Number of Squares error.

\[ SS_T = SS_A + SS_B + SS_{AXB} + SS_e \]

\[ SS_e = SS_T - SS_A - SS_B - SS_{AXB} \]  

(5)

The results of the analysis of variance do not prove the existence of differences in treatment and the influence of factors in the experiment, this proof is carried out hypothesis test F.

\[ F_{source} = \frac{\text{variance due to treatment + error variance}}{\text{variance due to error}} \]  

(6)

The pooling up strategy was designed by Taguchi to estimate the error variance in the analysis of variance. S / N ratio S / N ratio (Signal to Noise ratio) is used to select factors that have contributed to reducing the variation of a response. The S / N ratio used is that the smaller the quality characteristics, the better.

\[ S/N = -10 \log \left( \frac{1}{n} \sum_{i=1}^{r} Y_i^2 \right) \]  

(7)

3. Result and discussion

Before determining the orthogonal array matrix model that will be used, first determine the control factor by identifying the independent variables. Determination of control factors using a fishbone diagram, as shown below:

![Fishbone Diagram](image)

The control factors that are determined based on the control factors that have a level value include: coffee pulp (A), water (B), vinegar (C) and cooking time (D).
Based on the control factors that have been obtained, there are several interactions between the factors that occur are the interaction of factors AxB, factors AxC and factors AxD. The orthogonal array chosen is \( L_{8}(2^{7}) \), with a matrix like in Table 2. Table 3 shows in the recording there are two replications that are the same in an experiment with the same conditions to obtain more accuracy high on coffee pulp screen printing inks. The experimental results are obtained by conducting an experiment related to the four factors that were previously created according to a combination factor level matrix. This is done to obtain a more accurate estimate of the effect of a factor is done repetition (replication).

Table 4 shows the ranking of the factors of each level, after calculating the SNR difference of the two levels to determine the ranking of each factor. The factor that has the biggest difference is ranked first and so on. The ranking states how much influence or contribution to product quality Based on the calculation of Signal to Noise Ratio (SNR) can be obtained that the interaction between factors AxB level 1 has a large influence or contribution to the experimental results with an SNR value of 11.67 and less influential is the C level 1 factor with an SNR value of 11.13.

**Table 1. determining the number of levels and factor level values**

| Code | Control Factor       | Level 1     | Level 2     |
|------|----------------------|-------------|-------------|
| A    | Amount of Coffee Pulp| 0.5 Kg      | 1 Kg        |
| B    | Dose Of Water        | 0.5 Litre   | 1 Litre     |
| C    | Amount Of Vinegar    | 100 ml      | 200 ml      |
| D    | Cooking Time         | 10 Minutes  | 15 Minutes  |

**Table 2. Orthogonal Array Matrix**

| Eks | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-----|---|---|---|---|---|---|---|
|     | A | B | AxB | C | AxC | AxD | D |
| 1   | 1 | 1 | 1  | 1 | 1  | 1  | 1 |
| 2   | 1 | 1 | 1  | 2 | 2  | 2  | 2 |
| 3   | 1 | 2 | 2  | 1 | 1  | 2  | 2 |
| 4   | 1 | 2 | 2  | 2 | 1  | 1  | 1 |
| 5   | 2 | 1 | 2  | 1 | 2  | 1  | 2 |
| 6   | 2 | 1 | 2  | 2 | 1  | 2  | 1 |
| 7   | 2 | 2 | 1  | 1 | 2  | 2  | 1 |
| 8   | 2 | 2 | 1  | 2 | 1  | 1  | 2 |

**Table 3. Results of Experiments on Coffee Silk Screening Ink Products**

| Eks | 1 | 2 | 3 | 4 | 5 | 6 | 7 | total | Mean |
|-----|---|---|---|---|---|---|---|-------|------|
|     | A | B | AxB | C | AxC | AxD | D |       |      |
| 1   | 1 | 1 | 1  | 1 | 1  | 1  | 1 | 9     | 10   |
| 2   | 2 | 2 | 1  | 2 | 1  | 1  | 1 | 10    | 19   |
| 3   | 3 | 3 | 3  | 3 | 3  | 3  | 3 | 15    | 22.5 |
| 4   | 4 | 4 | 4  | 4 | 4  | 4  | 4 | 18    | 27   |
| 5   | 5 | 5 | 5  | 5 | 5  | 5  | 5 | 20    | 30   |
| 6   | 6 | 6 | 6  | 6 | 6  | 6  | 6 | 21    | 31.5 |
| 7   | 7 | 7 | 7  | 7 | 7  | 7  | 7 | 22    | 33   |
| 8   | 8 | 8 | 8  | 8 | 8  | 8  | 8 | 23    | 34.5 |

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Table 4. Ranking factors based on S / N ratio

| Factor/Level | A | B | A x B | C | A x C | A x D | D |
|--------------|---|---|-------|---|-------|-------|---|
| Level 1      | 11,30 | 11,10 | 11,67 | 11,13 | 11,29 | 11,50 | 11,40 |
| Level 2      | 10,87 | 10,94 | 10,51 | 11,04 | 10,88 | 10,83 | 10,77 |
| Difference   | 0,43 | 0,16 | 1,16 | 0,09 | 0,41 | 0,67 | 0,63 |
| Ranking      | 4 | 6 | 1 | 7 | 5 | 2 | 3 |

Table 5. Analysis Of Variance

| Sumber | DoF | SS  | MS  |
|--------|-----|-----|-----|
| A      | 1   | 1,23| 1,23|
| B      | 1   | 0,58| 0,58|
| AxB    | 2   | 8,19| 4,09|
| C      | 1   | 0,05| 0,05|
| AxC    | 2   | 1,17| 0,58|
| AxD    | 2   | 0,55| 0,27|
| D      | 1   | 2,69| 2,69|
| Error  | 1   | 4,32| 4,32|
| Total  | 11  | 18,78| -   |

Analysis of variance calculation of the number of squares error is used to find out the error that occurred obtained from the difference in the total number of squares with all average square and number of factor squares [7]. The results of these calculations obtained an error of 4,42 which is used to calculate the error in the analysis variance. With an error of 4,32 and a degree of freedom 1 an average square error is obtained (mean square) of 4,32.
Table 6. Polling Up Factors I

| Code | V | SS | MS |
|------|---|----|----|
| A    | 1 | 1,23 | 1,23 |
| B    | 1 | 0,58 | 0,58 |
| AxB  | 2 | 8,19 | 4,09 |
| C    |   |   | Pooling factor C |
| AxC  | 2 | 1,17 | 0,58 |
| AxD  | 2 | 0,55 | 0,27 |
| D    | 1 | 2,69 | 2,69 |
| Error| 2 | 4,37 | 2,18 |
| Total| 11| 18,78 | - |

Table 7. Polling Up Factors II

| Code | V | SS | MS |
|------|---|----|----|
| A    | 1 | 1,23 | 1,23 |
| B    | 1 | 0,58 | 0,58 |
| AxB  | 2 | 8,19 | 4,09 |
| AxC  | 2 | 1,17 | 0,58 |
| AxD  |   |   | Pooling Interaction Factor AxD |
| D    | 1 | 2,69 | 2,69 |
| Error| 4 | 4,92 | 1,23 |
| Total| 11| 18,78 | - |

Table 8. Polling Up Factors III

| Code | V | SS | MS |
|------|---|----|----|
| A    | 1 | 1,23 | 1,23 |
| B    |   |   | Pooling factor B |
| AxB  | 2 | 8,19 | 4,09 |
| AxC  | 2 | 1,17 | 0,58 |
| D    | 1 | 2,69 | 2,69 |
| Error| 5 | 5,50 | 1,10 |
| Total| 11| 18,78 | - |
Table 9. The results of the analysis of variance incorporating “polling up factors”

| Code | V | SS  | MS  |
|------|---|-----|-----|
| A    | 1 | 1,23| 1,23|
| AxB  | 2 | 8,19| 4,09|
| AxC  |   |     |     |
| D    | 1 | 2,69| 2,69|
| Error| 7 | 6,67| 0,95|
| Total| 11| 18,78| -  |

Tables 6.7.8.9 show the pooling done to collect insignificant factors are referred to as errors. Factor said no significant if the lowest SS value is obtained, Table 6.7.8.9 shows that factors C, D, AxD and AxC are not significant and is considered an error because the SS values of factors C, D, AxD and AxC have the smallest values so that the factors C, D, AxD and AxC are pooled up. By pooling factors C, D, AxD and AxC then obtained MSerror of 0.95 which was previously 4.32, which means a decrease error value.

Analysis of calculation of percent contribution is used to find out how much percent contribution of each factor to the quality of coffee pulp screen printing products [8]. The calculation of percent contribution is obtained from the comparison of the SSfactor value against SSTotal. From the calculation of the percent contribution, it was found that the interaction between factor A (coffe pulp) and B (water) had the largest contribution, namely 33.49%.

Table 10. Percent Distribution

| Code | DoF | SS  | MS  | SS’  | P%  |
|------|-----|-----|-----|------|-----|
| A    | 1   | 1,23| 1,23| 0,28 | 1,49|
| AxB  | 2   | 8,19| 4,09| 6,29 | 33,49|
| D    | 1   | 2,69| 2,69| 1,74 | 9,26|
| Error| 7   | 6,67| 0,95| -    | -   |
| Total| 11  | 18,78| -  | -    | -   |

Based on the data processing above, it is found that the factors that influence the quality of coffee pulp screen printing ink are coffee grounds (A) and Water (B). The quality characteristics used are Nominal is The best, then the selection of factor levels is based on the largest level value, namely the AxB factor level 1. so that it produces an optimal combination of settings A1, D1, AxC1, AxD1 and AxB1.
Table 11. Selected Combination Results

| Code | Factors               | Level     |
|------|-----------------------|-----------|
| A    | Amount of Coffe Pulp  | 0,5 Kg    |
| B    | Dose Of Water         | 0,5 Liter |
| C    | Amount Of Vinegar     | 100 ml    |
| D    | Cooking Time          | 10 Menit  |

Table 12. Confirmation trial results

| Experiment | Confirmation |
|------------|--------------|
| 1          | 9            |
| 2          | 10           |
| 3          | 10           |
| 4          | 9            |
| 5          | 10           |
| 6          | 9            |
| 7          | 10           |
| 8          | 10           |

From table 12, the assessment of whether or not the confirmation experimental results are accepted is done by comparing the confidence interval between the predicted results of the response under optimal conditions and the results of the confirmation experiment. Optimal prediction confidence interval obtained at 30.07 so that the optimal predictive confidence interval is $28.35 \leq 30.07 \leq 31.19$. Confirmation interval was obtained at 22.27 so that the interval is between $20.40 \leq \mu_{\text{predictions}} \leq 24.14$.

4. Conclusion
The conclusion of this research are:
1. After conducting research and experiments conducted on the floor of coffee pulp screen printing production on product quality, several conclusions can be drawn. Factors that significantly influence the quality of paving products among others are: Coffee Pulp factor by 1.49%, interaction of Coffee Pulp factor and Water Factor and Cooking Time factor by 9.26%.
2. The optimal combination of settings to reduce the number of defects and improve the quality caused by process factors and raw materials are 0.5 kg Coffee Pulp and Cooking Time 15 Minutes, then the optimum interaction level combination is 0.5 kg Coffee Pulp and 0.5 Liter Water, 0.5 kg Coffee Pulp and 10 Minute Cooking Time, 0.5 kg of coffee grounds and 100 ml vinegar. So that it can be concluded that the optimal combination obtained can improve quality by reducing the level of disability that occurs.

5. References
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