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# Application of Experiments Design Using Taguchi Method to Determine the Best Ingredient Composition in MSME Shrimp Crackers

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**Abstract:** Based on observations at the Shrimp Crackers MSME in Sawojajar Village, data was obtained regarding complaints from consumers regarding the problems they complained about, namely the crackers were not crispy enough, the crackers were broken and the prawns didn't taste good. This research aims to determine the composition of raw materials for shrimp cracker products at Shrimp Cracker MSMEs in Sawojajar Village using the Taguchi Method. In this research, three main factors were chosen to be studied, namely flour ratio, shrimp ratio, and water ratio, which are believed to have a significant effect on product quality. The study used Orthogonal Array $\mathbf{L_8(2^7)}$ to evaluate the influence of these factors on cracker quality. The analysis results show that the shrimp ratio and water ratio are significant factors that influence the quality of crackers. The water factor has the greatest influence with an F value of 764.4 and a P of 0.023, while the shrimp ratio shows an F value of 52.38 and a P of 0.087. Based on these results, MSMEs are advised to focus on optimizing the ratio of water to shrimp and implementing strict ingredient composition standards to maintain consistent product quality. In addition, worker training and regular evaluation of the production process are also recommended to ensure optimal cracker quality. Further research is recommended to evaluate other factors that might influence the quality of shrimp crackers.

**Keywords:** Ingredient Ratio, Orthogonal Array, Shrimp Crackers, Taguchi Method.

## 1. Introduction

Shrimp crackers are a snack food originating from coastal regions such as West Java, Jakarta, and Banten. These crackers are primarily made from shrimp mixed with flour and deep-fried to achieve their distinctive crunchy texture. Indonesia has many types of shrimp crackers, including rebon, koro, and asin. They have a savory, salty taste and crunchy texture, which is the main attraction of shrimp crackers as a complement to meals and snacks.

On the other hand, the product quality of shrimp crackers is influenced by various factors such as raw materials, production processes, and environmental conditions [**1**]. In this context, the Taguchi Experimentation Method approach is considered one of the effective methods of improving product quality by optimizing production factors.

Data regarding consumer complaints were obtained after conducting observations at MSMEs of Shrimp Crackers in Sawojajar Village. Technically, these complaints are submitted by consumers to the seller, who then conveys the complaint to the MSME. The data is grouped based on production batches, each consisting of 30 packs of shrimp crackers weighing 30 grams. However, not all consumers provide feedback.

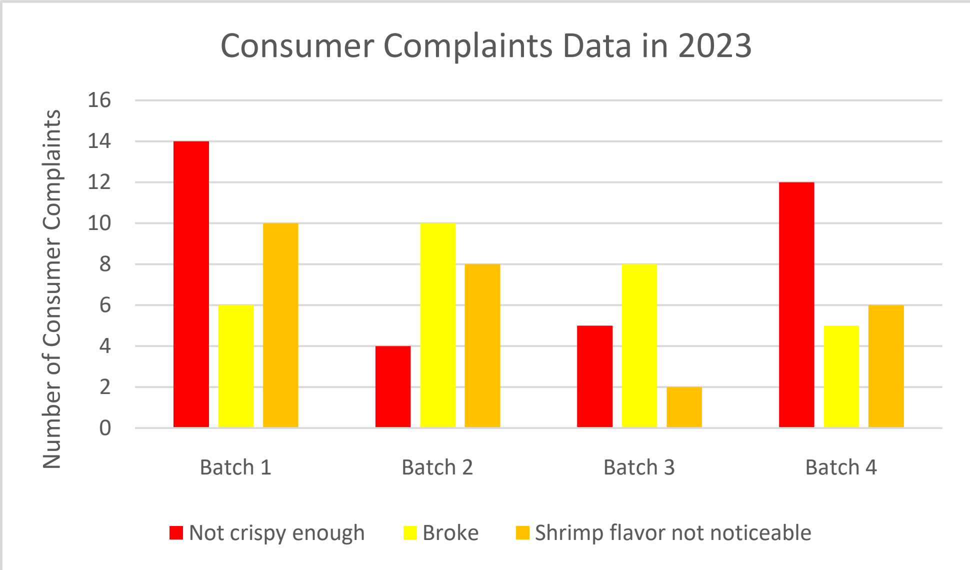


**Figure 1:**Data on Consumer Complaints on Shrimp Cracker Products

From the data provided, it can be seen that each production batch has different technical complaints.

1. Batch 1 had the most texture-related complaints, especially the lack of crispness, while flavor-related complaints were less dominant.
2. Batch 2 had complaints spread fairly evenly between lack of crispiness and breakage, with the number of lack of crispiness complaints drastically reduced from the previous batch.
3. Batch 3 had the fewest complaints, but the complaint of "shrimp flavor not noticeable" was less significant.
4. Batch 4 had the lowest number of breakage complaints, but the complaints of lack of crispness and shrimp tastelessness were significant.

After obtaining the data and discussing it with the owner, it was decided to focus further research on three critical factors: the flour ratio, shrimp ratio, and water ratio. These three factors were selected because they are believed to have a significant influence on the shrimp cracker final product's quality. Focusing on the ratio of these ingredients is expected to find the optimal composition that improves product quality and meets customer expectations and satisfaction.

## 2. Methods

The Taguchi Experimentation Method is an innovative technique that aims to improve product and process quality while reducing costs and resource usage. The method is designed to make products or processes "unaffected" by various factors, such as materials, manufacturing equipment, labor, and operational conditions. With this approach, the Taguchi method produces products or processes that are more robust to disturbances, so it is often referred to as robust design [**2**].

ThenGenichi Taguchi, a quality control consultant, presented three basic and simple concepts.

1. Quality Robustness
   Products must be manufactured to a high standard of quality without the need for inspection. Products should also be designed to be resistant to uncontrollable environmental variables.
2. Target Oriented Quality
   Quality is achieved by reducing the deviation from the set target value.
3. Quality Loss Function
   The cost of quality should be calculated based on how much it deviates from the specified standard, and the loss should cover the entire system. Taguchi emphasizes that the best way to improve quality is to integrate quality from the design stage so that well-designed products exhibit optimal performance.

In addition, quality is directly linked to non-conformance with specification limits (tolerances) that have been found, not to the deviation of design parameters from target values.

**2.1 Orthogonal Array**

Orthogonal Array is used in the Taguchi method to reduce the number of experiments required compared to traditional experimental design methods. Although this design still considers many factors and levels, the number of experiments that need to be performed is less, which can save time [**3**].

**Table 1:** Standard Orthogonal Array

| *Two-level series* | *Three-level series* | *Four-level series* | *Mixed-level series* |
|---|---|---|---|
| $L_4\ (2^3)$ | $L_9\ (3^4)$ | $L_{15}\ (4^5)$ | $L_{18}\ (2^1,\ 3^7)^\dagger$ |
| $L_8\ (2^7)$ | $L_{27}\ (3^{13})$ | $L_{64}\ (4^{21})$ | $L_{36}\ (2^{11},\ 3^{12})$ |
| $L_{16}\ (2^{15})$ | $L_{81}\ (3^{40})$ | | |
| $L_{32}\ (2^{31})$ | | | |
| $L_{12}\ (2^{11})^*$ | | | |

In creating an orthogonal matrix, it is important to know in advance the number of factors and levels to be used, as well as the degrees of freedom. The degree of freedom (df) is a measure represents the number of trials needed to obtain the required information [**4**].

**Table 2:** Degrees of Freedom

| Factor / Interaction | Degrees of Freedom |
|---|---|
| Overall Mean | 1 |
| Factor with 2 levels | (KA – 1) |
| Factor with 3 levels | (KB – 1) |
| Interaction factor | (KA – 1) x (KB – 1) |
| Total df | Sum of all df |

Description:
KA = Number of levels of factor A
KB = Number of levels of factor B

**2.2 Signal to Noise Ratio**

The Signal-to-Noise (S/N) ratio can identify factors affecting response variation. Taguchi changes from repeating data to a new value that measures the current variation. The S/N ratio is used to find out which factors affect the experimental results. The calculation of the S/N ratio is done based on the intended quality attribute.

A quality characteristic is the product of a quality-related process. The calculation method of the S/N ratio depends on the quality characteristics of the response, which means that the smaller, the better, the larger, the better, or it is fixed at a specific value [**5**].

$$S/N = -10\log_{10}(\mathrm{MSD}) \qquad (1)$$

Description:
Mean Squared Deviation (MSD) = The mean squared deviation from the target value of a quality trait

Taguchi classifies quality characteristics into three categories, namely [**6**]:

1. Smaller is better
   S/N ratio calculation formula *smaller is better*:
   $$S/N = -10\log_{10}(\mathrm{MSD})$$
   $$= -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} Yi^2\right) \qquad (2)$$

2. Nominal is the best
   S/N ratio calculation formula *Nominal is the best*:
   $$S/N = -10\log_{10}\frac{\pi^2}{\sigma^2}$$
   $$\pi = \frac{1}{n}\sum_{i=1}^{n} Yi^2)$$
   $$\sigma = \frac{1}{n}\sum_{i=1}^{n}(Yi - \mu)^2 \qquad (3)$$

3. Larger is better

The formula for calculating the S/N ratio *larger is better* :

$$S/N = -10\log_{10}(MSD)$$

$$= -10\log_{10}\left(\frac{1}{n}\sum_{n=1}^{n}\frac{1}{Yi^2}\right) \quad (4)$$

Description:
n = Number of repetitions
Yi = i-th observation data (i = 1,2,3,...., n)

### 2.3 Analysis of Variance

Sugianto explains that Analysis of Variance (ANOVA), part of the Taguchi approach, is used to analyze experimental data [**7**]. This method allows calculations to estimate the contribution of each factor to each response measurement. When applied to parameter design, variance analysis helps determine the contribution of these factors so that the estimation model can be evaluated appropriately.

The nature of the level of each factor in ANOVA analysis is fixed, which means that the level of each factor is fixed in number and used throughout the experiment. In the analysis of variance with an x b factorial experiment, the model used is fixed.

**Table 3:** Two-way ANOVA

| Source of Variation | Free Degree (db) | SS | MS | F Count | Percent Contribution |
|---|---|---|---|---|---|
| Factor A | VA | SSA | MSA | MSA/MSE | SS'A/SST |
| Factor B | VB | SSB | MSB | MSB/MSE | SS'B/SST |
| AxB interaction | VA x VB | SSA x SSB | MSA x B | MSA x B/MSE | SS'A x B/SS'T |
| Residuals | VE | SSE | SSE | | SS'E/SS'T |
| Total | VT | SST | | | 100% |

### 2.4 Factor Pooling

Factor pooling is the process of combining factors with the most minor significance into error categories. The purpose of pooling is to avoid overestimation and reduce experiment errors [**8**].

## 3. Results and Discussion

Data processing using Minitab was conducted through the following steps:
1. Running the Minitab application program.
2. Choose an experimental design with two levels and three factors.
3. Choosing a $L_8$ Taguchi design.
4. Copying and pasting the experimental response results into the worksheet.
5. Analyzed the Taguchi design and calculated the SN ratio using the *"smaller is better"* method.

After processing the data using Minitab, the resulting summary model is shown in the following table:

**Table 4:** Model Summary (Minitab Data Processing)

| *S* | *R-Sq* | *R-Sq (adj)* |
|---|---|---|
| 2.2981 | 99.53% | 96.68% |

### 3.1 Factors and Levels

Several factors affecting the quality of shrimp crackers were identified through literature review, consumer complaints, and consultations with MSME owners. These factors include flour proportion, shrimp proportion, and water proportion. Each factor has two different levels, namely:

Shrimp Ratio: Level 1: 13 grams
Level 2: 15 grams
Flour Ratio: Level 1: 22 grams
Level 2: 24 grams

Water Ratio: Level 1: 500 ml
Level 2: 600 ml

The each combination of these factors and levels can produce 60 crackers. Onion was used as a control factor, with the same amount applied in all replications. The next step in this study is to calculate the Degrees of freedom (df) for each factor. Based on the table of degrees of freedom given:

1. The flour, shrimp, and water factors each have a degree of freedom of 1 (2-1 = 1).
2. For the interaction between flour and water, flour and shrimp, and shrimp and water each also has a degree of freedom of 1 ((2-1).(2-1) = 1).
3. The total degrees of freedom calculated in this study are 6 (df = 6).

### 3.2Orthogonal Array

In this study, there are three factors with two levels; the number of experiments that must be made is eight times the experiment, corresponding to the orthogonal array $L_8(2^7)$. Here is the orthogonal array table.

**Table 5:** Orthogonal Array (Data Processing)

| *Flour (A)* | *Shrimp (B)* | *Water (C)* | *Flour*Shellfish (AB)* | *Flour*Water (AC)* | *Shrimp*Water (BC)* | *y1* | *y2* |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 15 | 8 |
| 1 | 1 | 2 | 1 | 2 | 2 | 40 | 45 |
| 1 | 2 | 1 | 2 | 1 | 2 | 10 | 13 |
| 1 | 2 | 2 | 2 | 2 | 1 | 25 | 22 |
| 2 | 1 | 1 | 2 | 2 | 1 | 12 | 11 |
| 2 | 1 | 2 | 2 | 1 | 2 | 35 | 40 |
| 2 | 2 | 1 | 1 | 2 | 2 | 13 | 10 |
| 2 | 2 | 2 | 1 | 1 | 1 | 24 | 26 |

Description:
Y1: Response result from experiment 1
Y2: Response result from experiment 2

The degrees of freedom for each factor used in the research to improve the quality of shrimp cracker products using the Taguchi Experiment Method. The factors analyzed include flour, shrimp, and water, as well as the interaction between flour and water, flour and shrimp, and shrimp and water.

Each main factor (float, shrimp, and water) has two levels, so the degree of freedom for each of these factors is 1, which is calculated by the formula 2-1 = 1. Furthermore, for interactions between factors (flour*water, flour*shrimp, and shrimp*water), the degree of freedom is calculated by multiplying the degrees of freedom of each interacting factor. Since each factor has 1 degree of freedom, the calculation for each interaction is (2-1)×(2-1)=1, (2-1)×(2-1) = 1, (2-1)×(2-1)=1.

Thus the total degrees of freedom for this study amount to 6, which is the sum of the degrees of freedom of each factor and its interaction. A proper understanding of these degrees of freedom is very important in statistical analysis, especially in the Taguchi Experimental Method, as it affects the calculation of the variability and significance of each factor's effect on the quality of shrimp cracker products. This analysis ensures that each factor and its interaction is correctly accounted for so that the results can be used to optimize the production process and improve product quality effectively.

This research uses Orthogonal Array $L_8(2^7)$ as the experimental design, resulting in 8 trial combinations. The use of Orthogonal Array $L_8(2^7)$ allows this study to test the main effects of the three factors as well as some interactions between factors. The researcher can save time and resources compared to conducting a complete factorial experiment, which would require eight trials.

After the experiment, the following results were obtained:

**Table 6:** Experiment Result Data

| *y1* | *y2* |
|---|---|
| 15 | 8 |
| 40 | 45 |

| | |
|---|---|
| 10 | 13 |
| 25 | 22 |
| 12 | 11 |
| 35 | 40 |
| 13 | 10 |
| 24 | 26 |

The table above shows the number of defects in each treatment. The crispness and flavor of the crackers determines the defect factor. The variable y1 is the response result of the first experiment, and y2 is the response result of the second experiment. After obtaining the experimental results, the next step is data processing using Minitab software.

**3.3Response Table**

The next stage is preparing the response table. The table is prepared by adding the response value corresponding to each level (level 1 and level 2) of each factor.

**Table 7:** Response Table (Data Processing)

| *Factor* | *Flour* | *Shrimp* | *Water* | *Flour*Shellfish* | *Flour*Water* | *Shrimp*Water* |
|---|---|---|---|---|---|---|
| Level 1 | 178 | 206 | 92 | 181 | 171 | 143 |
| Level 2 | 171 | 143 | 257 | 168 | 178 | 206 |

The next step is to compile the average response table and rank the level differences of each factor.

**Table 8:** Average Response and Ranking (Data Processing)

| *Factor* | *Flour (A)* | *Shrimp (B)* | *Water (C)* | *Flour*Shellfish (AB)* | *Flour*Water (AC)* | *Shrimp*Water (BC)* |
|---|---|---|---|---|---|---|
| Level 1 | 44,50 | 51,50 | 23,00 | 45,25 | 42,75 | 35,75 |
| Level 2 | 42,75 | 35,75 | 64,25 | 42,00 | 44,50 | 51,50 |
| Difference | 1,75 | 15,75 | 41,25 | 3,25 | 1,75 | 15,75 |
| Rank | 6 | 2 | 1 | 4 | 5 | 3 |
| | | | | | Grand Total | 523,50 |
| | | | | | Y | 32,72 |

The difference between level 1 and level 2 shows the impact of changes in each factor. The water factor has the most significant difference (41.25), followed by shrimp*water (15.75), shrimp (15.75), flour*water (1.75), and flour*shrimp (3.25), indicating that the water factor has the most significant influence in this process. Factor rankings showed the priority of influence, with water ranked first, followed by shrimp*water, shrimp, flour*shrimp, and flour*water. The total response value was 523.50, with a mean (Y) value of 32.72.

Furthermore, the calculation for μ prediction is carried out with the following formula:

$$\mu \text{ prediction} = \overline{C}1 + \overline{B}2 + \overline{BC}1 - 2\overline{Y}$$
$$= 23{,}00 + 35{,}75 + 35{,}75 - 65{,}44$$

= 29,06 defects per batch

Description:

$\overline{C}1$ : level 1 average response

$\overline{B}2$ : level 2 average response

$\overline{BC}1$: level 1 shrimp*water interaction response

The calculated predicted μ value is 29.06. This value was obtained from the average of all responses, which was 32.72, taking into account the contribution of the three most influential factors affecting the quality of shrimp crackers: water at level 1, shrimp at level 2, and the interaction between shrimp and water at level 1.

**3.4Analysis of Variance (ANOVA)**

The following are the ANOVA results from data processing using Minitab.

**Table 9:** Analysis of Variance for Mean

| *Source* | *DF* | *Seq SS* | *Adj SS* | *Adj MS* | *F* | *P* |
|---|---|---|---|---|---|---|
| Flour | 1 | 1.53 | 1.531 | 1.531 | 0.29 | 0.686 |
| Shrimp | 1 | 124.03 | 124.031 | 124.031 | 23.49 | 0.130 |
| Water | 1 | 850.78 | 850.781 | 850.781 | 161.09 | 0.050 |
| Flour*Shellfish | 1 | 5.28 | 5.281 | 5.281 | 1.00 | 0.500 |
| Flour*Water | 1 | 1.53 | 1.531 | 1.531 | 0.29 | 0.686 |
| Shrimp*Water | 1 | 124.03 | 124.031 | 124.031 | 23.49 | 0.130 |
| Residual Error | 1 | 5.28 | 5.281 | 5.281 | | |
| Total | 7 | 1112.47 | | | | |

The results of the ANOVA analysis in the table show that the factors tested were flour, water, shrimp, and the interaction between each factor. The flour factor had an F value of 0.29 and a P value of 0.686. The shrimp factor had an F value of 23.49 with a P value of 0.130. The water factor showed an F value of 161.09 with a P value of 0.050. The interaction between flour and shrimp had an F value of 1.00 with a P value of 0.686. The interaction between flour and water had an F value of 0.29 with a P value of 0.686. The interaction between water and shrimp had the highest F value of 23.49, and its P value was 0.130.

### 3.5 Factor Pooling

Factor pooling is a technique used in Taguchi Experimental Method data analysis to combine the effects of insignificant factors into the error to improve the reliability and accuracy of the analysis results. This helps simplify the model and ensures that only significant factors are used for process optimization. The following are the results of factor pooling.

**Table 10:** Factor Pooling

| *Source* | *DF* | *Seq SS* | *Adj SS* | *Adj MS* | *F* | *P* |
|---|---|---|---|---|---|---|
| Flour | 1 | 1.53 | 1.531 | 1.531 | 0.29 | 0.686 |
| Shrimp | 1 | 124.03 | 124.03 | 124.03 | 23.49 | 0.130 |
| Water | - | - | - | - | - | - |
| Flour*Shellfish | 1 | 5.28 | 5.281 | 5.281 | 1 | 0.500 |
| Flour*Water | 1 | 1.53 | 1.531 | 1.531 | 0.29 | 0.686 |
| Shrimp*Water | 1 | 124.03 | 124.03 | 124.03 | 23.49 | 0.130 |
| Residual Error | 1 | 5.28 | 5.281 | 5.281 | | |
| Total | 7 | 1112.5 | | | | |
| Pooled Factor | 6 | 261.68 | | 43.613 | | |

The table above shows the insignificant factors (flour, shrimp, flour*shrimp, flour*water, and shrimp*water) were pooled to simplify the model. The pooling results showed pooled DF = 6, pooled SS = 261.68, and pooled MS = 43.61.

## 4. Conclusion

Based on the results of the analysis using the Taguchi Method with Orthogonal Array $L_8(2^7)$, the optimal proportion of raw materials for shrimp crackers is obtained as follows:

- Flour (levels 1 and 2): 22 and 24 grams
- Shrimp (level 2): 15 grams
- Water (level 1): 500 ml

The calculation resulted in a value of 29.06 defects per batch. This value is obtained from the overall average response of 32.72, considering the contribution of the three most influential factors affecting the quality of shrimp crackers: water at level 1, shrimp at level 2, and the interaction between shrimp and water at level 1.

The optimal raw material composition obtained in this study can serve as a standard for MSMEs producing shrimp crackers. By following the optimal raw material composition, MSMEs can ensure the consistency and quality of standardized shrimp crackers. This standard is expected to help MSMEs improve and maintain the quality of their products so that they can meet consumer satisfaction and compete in a competitive market.

## References

[1] Hidayatullah, M. S. “Peningkatan Kualitas Produk Kerupuk Dengan Menggunakan Pendekatan Metode Taguchi Di Sentra Produksi Kerupuk Ikan Desa Srowo”, 2019.
[2] Soejanto, I. “Desain Eksperimen dengan Metode Taguchi”, Yogyakarta: Graha, 2009.
[3] Ross, P. J. “Taguchi Techniques for Quality Engineering: Loss Function, Orthogonal Experiments, Parameter and Tolerance Design”, New York: McGraw-Hill, 2005.
[4] Kurniawan, I. “Perancangan Eksperimen Untuk Meningkatkan Kualitas Produk Kerupuk Palembang Dengan Menggunakan Metode Taguchi”, 2010.
[5] Taguchi G, Chowdhury S, Yuin Wu. “Taguchi’s Quality Engineering Handbook”, John Wiley & Sons, Inc. Printed in theUnited States of America; 2004.
[6] Belavendram, T.P. “Taguchi Method Explained: Practical Step to Robust Design”,New Delhi: Prentice Hall of India Pritative Limited, 1995.
[7] Sugianto, A. “Peningkatan Kualitas Produk Sabun Translucent dengan Pendekatan Taguchi (Study Kasus: PT.Wilmar Nabati Indonesia)”, Jurusan Teknik Industri, Universitas Muhammadiyah Gresik, 2016.
[8] Halimah, P. “Penerapan Metode Taguchi untuk Meningkatkan Kualitas Bata Ringan pada UD. XY Malang”, Journal of Industrial Engineering and Management Systems, 2020.

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